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ABSTRACT

This is the second volume of a two volume study. The first volume examined the literature to identify authoring aids for developing instructional materials, and to identify information clearing houses for existing materials. The purpose of this volume was to develop a means for assessing the cost versus expected benefits of innovations in computer-based training systems. A three-pronged approach was used to address the problem. First, a descriptive model of a generalized, computer-based training system was developed. Second, a predictive model was generated to describe student performance in a computer-based training environment. Third a computer program incorporating the predictive model was developed to estimate the cost of implementing one particular training innovation, i.e., revision of a conventional instructional program into a self-paced instructional program. A linear prediction model was developed to predict the time required for a student to complete a unit of self-paced instruction, thereby demonstrating the time saved by converting from a conventional instructional mode. This was combined with the Rand Corporation's MODIA cost analysis program. The study demonstrated that a viable time savings and cost model can be developed, given a sufficient data base from which to draw the necessary course content and student characteristics descriptions. (Author/DAG)

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A SURVEY AND ANALYSIS OF MILITARY COMPUTER-BASED TRAINING SYSTEMS: (A TWO PART STUDY)

15 MAY 1977 VOLUME II MDC E1570

A DESCRIPTIVE AND PREDICTIVE MODEL FOR EVALUATING INSTRUCTIONAL SYSTEMS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objectives of this study were: (1) to examine the literature to identify authoring aids for developing instructional materials and to identify information clearing houses for existing instructional materials; and (2) to develop a generalized, computer-based model of a self-paced instructional system that can be used to determine expected time-savings and costs of self-pacing as compared to conventional instruction. The purpose of Part 1, reported in Volume I, was to examine the ISD concept as it relates to the authoring process and analyze tools and procedures which facilitate the ISD process. The purpose of

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Part 2, published in Volume II, was to develop a means for assessing the cost versus expected benefits of innovations in computed-based training systems. A three-pronged approach was used to address the problem. First, a descriptive model of a generalized, computer-based training system was developed. Second, a predictive model was generated to describe student performance in a computer-based training environment. Third, a computer program incorporating the predictive model was developed to estimate the cost of implementing one particular training innovation, i.e., revision of a conventional instructional program into a self-paced instructional program. A linear prediction model was developed to predict the time required for a student to complete a unit of self-paced instruction thereby demonstrating the time saved by converting from a conventional instructional mode. This was combined with the Rand Corporation's MODIA cost analysis program. The study demonstrated that a viable time savings and cost model can be developed given a sufficient data base from which to draw the necessary course content and student characteristics descriptions.

PREFACE

This study was conducted under Contract MDA-903-76-C-0086 with the Department of Defense, Advanced Research Projects Agency, Cybernetics Technology Office. The DoD Program Manager was Dr. Harold F. O'Neil, Jr. The Principal Investigator was Dr. Robert A. Vecchiotti, McDonnell Douglas Astronautics Company - East (MDAC-EAST).

The contributors to this report are listed in alphabetical order: Dr. Donald W. Carver, Mr. Edmund H. Conklin, Drs. Donald R. Hesser, Wilson A. Judd, Barbara L. McCombs, George D. Siering, and Robert A Vecchiotti. The contributors wish to express their appreciation for the cooperation and suggestions of personnel from the Air Force Human Resources Laboratory - Technical Training at Lowry Air Force Base, Colorado, and to their colleagues on the Air Force Advanced Instructional System Program for their contributions, particularly Mr. William H. Stobie. Special thanks are due to Ms. Polly Carpenter-Huffman of the Rand Corporation for arranging the use of the Method of Designing Instructional Alternatives (MODIA) cost model.

SUMMARY

PROBLEM

Within the context of military training system development, the question of how to assess the cost versus expected benefits of innovations in training technology has become of major importance. Before this question can be answered, it must first be demonstrated that both the cost and the benefits of such innovations can be quantitatively measured. Then it must be demonstrated that accurate predictions can be made with regard to development and operational costs, training effectiveness, and expected timesavings.

APPROACH

Three separate activities were undertaken to solve this problem. The first was to define a descriptive model of a generalized, computer-based training system. This model defined the domain of such systems to be addressed by a predictive model. It also identified the component activities involved in such a training system, isolated seven clusters of factors which would impact the operation of the system, and identified the relationship of each cluster to the separate component activities.

The second step was generation of a predictive model of student performance in a computer-based training environment. The purpose of this model was to predict the time required for a student to complete an arbitrary unit of instruction in a self-paced training program given only characteristics of the student, of the content taught, and of the method employed to teach the content in a conventional, lock-step course.

The third activity was to develop a computer program which incorporated the predictive model and estimated the cost of implementing and operating this particular, innovative training technique, i.e., conversion from conventional lock-step to self-paced, computer-based instruction.

RESULTS

A linear prediction model was developed to predict a student's time required to complete his first attempt on a given lesson. Fourteen predictor variables were selected, eleven descriptive of the instructional course content and three descrip-

tive of student characteristics. The final regression equation produced on R = .63 accounting for 39 percent of the variance in a student's first-attempt-lesson time. When the regression equation was validated on a second sample, the R^2 resulted in a loss of only 5.34 percentage points in accounting for the variance in the criterion variable, first-attempt-lesson time. The basic model was then modified to predict total course completion time.

A computer program, "Aid for Instructional Development and Evaluation (AIDE)," was written. It is a modification of Rand Corporation's MODCOM cost analysis program. It retains all of the cost-analysis features and outputs of MODCOM while allowing course completion time to be estimated by the regression equation developed in this study. Course completion times and cost estimates were generated for a standard sample and three additional samples in which student or course content characteristics were varied.

CONCLUSIONS

This study demonstrated that a viable model can be developed which predicts the costs and timesavings associated with individualization of an arbitrary training course through the use of a computer-based training system. The generality and precision of such a model is dependent on the breadth and accuracy of the data base from which the model is derived. Although the data base employed in this study was not as complete as could be desired, the resultant model was found to be reasonably accurate and is sufficiently general to be of value in the evaluation of courses for individualization. More importantly, a methodology has been developed and demonstrated which will become an even more useful tool as additional data are accumulated from computer-based training systems.

The results of exercising the AIDE program illustrated the impact of variations in course content on the timesavings to be expected from individualization. Current methods of instruction, methods employed in the course as it is taught in conventional, lock-step mode were found to be sensitive indicators of variations in course content and, hence, of expected timesavings. Thus, performance oriented training, for which the Plan of Instruction indicates a relatively high proportion of demonstration-performance activities, presents less promise for individualization than do courses containing a high proportion of cognitive and, particularly, memorization content.

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1.0 INTRODUCTION

1.1 BACKGROUND

A question of primary importance to those concerned with the design, development, implementation, or evaluation of innovations in training technology is one which addresses the cost and effectiveness of such innovations. Within the context of military training system development, interest has recently been focused on this question as it relates to innovations in the area of computer-based training (CBT). Here the concern has been one of not only attempting to find means for evaluating the actual benefits attributable to the innovation relative to its cost, but also to find a means for evaluating the expected benefits. That is, before large sums of money are invested in computer-based training innovations, it is important to know (a) whether the benefits and costs associated with the innovations can be quantitatively evaluated and (b) whether cost-effectiveness data to support implementation decisions can be predicted, given quantifiable information on training system parameters and their interactions with trainee and training material characteristics.

To address the preceding concern adequately, both descriptive and predictive models of a computer-based training system are required. Descriptive models serve the purpose of identifying the relevant parameters affecting cost and effectiveness decisions and of indicating the degree to which these parameters may be quantified. Predictive models serve the purpose of calculating expected outcomes, given information on the descriptive parameters and the relationships between them. A major problem, however, is that appropriate descriptive and predictive models have not been sufficiently integrated in an operational decision model which can be used in planning cost-effective implementations of CBT innovations.

The present study was undertaken to address this need. The specific goals and objectives of the effort are described in the following section, after which the types of problems involved in the development, integration, and validation of descriptive and predictive CBT models are discussed in a literature review.

1.2 GOALS AND OBJECTIVES

The goals of the present study were threefold: (1) to define and describe those computer-based training system parameters likely to affect cost-effectiveness decisions, i.e., to produce a descriptive model of a generalizable CBT system, including all relevant instructional, student, and training system variables; (2) to model, as accurately as possible, anticipated student performance in the generalized system described; and (3) to produce an operational computer model which will incorporate the predicted student and system performance data and can be used to calculate the expected costs and benefits of implementing selected CBT innovations.

To meet the preceding goals, the following objectives were specified:

a. To describe the CBT characteristics expected to be related to measureable outcomes.

b. To identify those outcomes that most reflect "benefits" attributable to innovations, e.g., student training time reduction and decreased elimination rates.

c. To specify the relationships and interactions between all system parameters.

d. To identify those parameters for which quantifiable data are available.

e. To determine the type of modeling procedures most appropriate for the predictive model, e.g., appropriate statistical or mathematical models for predicting benefits and costs.

f. To integrate the predictive model in a computer program that can be used as a planning aid.

The anticipated and actual problems related to these goals and objectives are discussed and summarized in the following section.

1.3 LITERATURE REVIEW

1.3.1 Selection of Criterion Variable - Only a few pertinent reports concerning the quantification of learning system features in terms of time-to-complete a unit of instuction, student performance, and training cost were identified. A seminal study reported by Wagner, Behringer, and Pattie (1973) addressed the description of training system features which predicted course completion time. Their study combined course-related instruments and standardized aptitude tests to predict time-to-complete. These devices included:

- o Tests of skills and knowledge necessary for the acquisition of certain military occupational specialties
- o Tests that sampled the content of the tasks to be learned during the course
- o Scales designed to measure motivational factors related to the subject matter of the course.

A step-wise multiple linear regression analysis was applied to the data. Correlations between the predictor variables and course completion time ranged from .65 to .87. These results supported the hypothesis that course-related predictors are better than measures of general aptitude in estimating the time-to-complete a course of instruction. In addition, the authors accepted the hypothesis that the relationship between course-related predictors and completion time variables is linear.

As an attempt to categorize and integrate the diverse variables influencing the instructional process, Carroll (1962, 1963) presented a conceptual model of school learning which has proven to be quite durable over the intervening fourteen years. The model output, the criterion variable, is degree of learning, i.e., performance on an achievement test after a fixed amount of elapsed time. The model itself consists of five elements, two pertaining to the characteristics of the instructional environment, and three to the characteristics of the student. The first instructional variable concerns the adequacy of presentation of the learning task, how clearly it is presented and explained, and how appropriately it is placed in the sequence of tasks to be learned. The second represents the opportunity for learning, the time allowed to learn the task. The first of the three individual difference variables represents the student's ability to understand the instruction. Carroll suggests this to be analogous to general or verbal intelligence and determines the extent to which the student is able to understand directions and explanations or to infer them from the content of instruction if they are missing. The second, aptitude, is defined as the time needed by the student to learn a particular task to criterion, given that the instruction is presented well enough for him to grasp it. Aptitude is considered to be a relatively invarient characteristic of the individual. The third element represents the maximum amount of time an individual will apply himself to a task This is called perseverance.

A recent model of the instructional process proposed by Cooley and Lohnes (Glaser, 1976) deviates only slightly from Carroll's earlier formulation. Carroll's elements of aptitude and ability to understand instruction are replaced by a single variable, initial ability, representing the sum of the student's skills and intellectual capacities. Carroll's adequacy of presentation is replaced by two elements: (a) the extent to which the curriculum is structured, the methods of individualizing instruction, and the general organization of instruction; and (b) the quality of the student-teacher interaction. The term motivation has been substituted for perseverance, but it is defined as the student's tendency to engage in learning activities when the opportunity exists. Finally, the relationships among the elements are not stated as explicitly. Rather, these relationships are to be determined empirically through multivariate analysis.

Neither the Carroll nor the Cooley and Lohnes model, as stated, is appropriate to a self-paced, criterion-referenced instructional environment. In both, the criterion variable represents degree of learning, and opportunity for learning is assumed to be limited. In a criterion-referenced environment, degree of learning is, theoretically at least, controlled while opportunity for learning remains free to vary. Consequently, time per unit of instruction (time to criterion) or learning rate is the most appropriate criterion variable for a model of learning in a self-paced environment.

1.3.2 Selection of Predictor Variables - Psychologists and educators have long been aware that learning and performance on instructional tasks are a function of the student's level of ability or aptitude and his motivation. More recently, they have also recognized the importance of taking into account both situational and task factors. The search for those variables, however, and their associated measures which best describe the student's actual and expected performance remains a pervasive problem further complicated by:

- o The difficulty in obtaining quantitative measures of situational and task variables (Uprichard, 1975)
- o The fact that a student's trait levels of ability and motivation may not be as predictive of his performance as more situationally sensitive state measures (Speilberger, 1966; Spielberger, O'Neil, and Hansen, 1972)

- The limited progress that has been made in the identification of satisfactory measures of student motivation (Bem and Allen, 1974).

Additional problems are raised when the concern is prediction of performance in a self-paced, individualized, criterion-referenced instructional environment. A majority of research on variables related to learning has been conducted in group-paced, conventional instructional environments, (Campbell and Schwen, 1971; Schwen, 1973), and existing theories and data on ability and motivational variables have focused on achievement scores rather than learning rates as the dependent variable of interest (Brown and James, 1972; Colton, 1974; McAvoy, Kalin, and Franklin, 1973).

1.3.2.1 Student Ability/Aptitude - A common approach to the problem of identifying student characteristics related to performance in a complex instructional system is some form of task analysis. Campbell and Schwen (1971) argue for an analysis of learning tasks in terms of the effects they have on the student's cognitive processes and personality variables. They stress that possible interactions between task and learner characteristics be considered. Schwen (1973) suggests that a model most appropriate for analysis of learner characteristics is one that combines empirical methods, e.g., predictive statistical models, with task analysis. The important point is that such analytical methods can be used to identify potentially important variables or interactive relationships between variables that should be considered in a student ability/aptitude parameter.

1.3.2.2 Situational/Task Variables - In considering relevant situational/task variables, it is instructive to distinguish between those variables which may vary between students, such as type of instructional treatments, and those which are constant for an individual student but vary across tasks, e.g., criterion levels or task difficulty. Just as analyses of learning tasks and learner characteristics were recommended for the identification of an ability/aptitude parameter, it is an equally appropriate approach to the identification of relevant situational/task variables (Campbell and Schwen, 1971; Schwen, 1973). Walberg (1975) has stressed the need for analyses which identify other possible variables predictive of student performance. He bases this on the fact that, although aptitudes or abilities can be reliably measured, they can usually account for no more than half the variance in student performance. Uprichard (1975) suggests that organizational stucture or classroom variables be taken into account as well as evaluation variables, e.g., criterion levels and frequency of tests.

Some additional situational/task variables which may be important in a self-paced instructional environment are suggested by the Wagner et al (1974) study. Among their findings were:

- o Total time could not be predicted as well as instructional time due to many unknown factors related to variabilities in testing time
- o Grouping of data by instructional mode was required in order to predict completion times more accurately.

These findings suggest that potentially important situational/task variables would include ratios of instructional time to testing time, relative difficulty level of each instructional unit of interest, testing frequency, ratio of audio-visual to printed materials, and the frequency with which an adaptive model choice (if present in the system) constitutes the actual assignment.

2.0 OVERVIEW OF THE TECHNICAL APPROACH

The work described herein consists of three major activities:

a) Definition of a descriptive model of a generalized, computer-based training system.

b) Generation of a predictive model of student performance in a computer-based training environment.

c) Development of a computer program incorporating the predictive performance model to estimate the cost of such a system.

The primary purpose of the descriptive model was to identify the component activities involved in the instructional process in a computer-based training environment. Further, the model served to identify: (a) subject matter characteristics; (b) instructional and system design considerations; (c) student individual difference characteristics; and (d) the relationship of these variables to the various components of the model. The variables to be considered by the predictive model served to define the domain of computer-based training systems to be addressed by the predictive model. As defined, the model assumed a criterion referenced testing environment and emphasized, as the dependent variable, the time to reach criterion on an arbitrary unit of instruction.

Since this study focused on the prediction of student time-to-completion of a unit of instruction (so as to demonstrate time-savings and cost-effectiveness), a model to account for prediction of time was developed. The analysis of data within this model necessitated the use of a statistical technique through which one can analyze the relationship between the criterion or dependent variable and a set of predictor or independent variables.

The statistical technique chosen for this effort was multiple regression. This statistical treatment is useful primarily because of its ability to produce linear prediction equations (Kerlinger and Pedhazer, 1973) as well as computing statistics that provide the researchers with statistical inference procedures for determining confidence limits for estimates with a means for measurement of variance in the dependent variable accounted for by the predictor set. Finally, the use of multiple regression provided the authors with a degree of control over extraneous variables in order that the combined contribution of a specific set of variables could be more closely examined.

Specifically, the intent was to develop a model in the form of a regression equation in which the criterion was time-to-complete an arbitrary instructional unit. Predictor variables were drawn from the several categories defined by the descriptive model and were limited to the type of information which will be available to or can easily be obtained by a military training course developer. The actual predictor variable data were sampled from course planning documents for two courses which had been group-paced but are currently being conducted in a self-paced mode under the control of a computer-based training system - - the Advanced Instructional System (AIS) at Lowry Air Force Base, Colorado.

The predictor variables fell into four broad categories. The first concerned course content, information which was either available directly from the course planning documents or which could be derived from these documents. The second category consisted of instructional design considerations. Variables in this category were broadly defined and limited by the consideration of only those which varied between or within the two AIS courses. The third consisted of test characteristics, the performance standards established for the two courses. The fourth category of predictor variables consisted of student individual difference measures. Two classes of such measures were considered: those which would normally be available to the developers of a military training course; and an additional set of measures which was available to this study because of its use in the AIS pre-assessment battery.

The criterion variable explicitly predicted by the regression equation is first-attempt-time on an AIS lesson. The model was then expanded to address the time required to complete a larger instructional unit consisting of n lessons and an end-of-unit criterion test. Lesson and unit level criterion data were drawn from the AIS student performance data bases for the Inventory Management and Weapons Mechanic courses.

The most relevant predictors in each of the four categories of predictor variables were determined through a series of linear model comparisons. In such comparisons, two equations, one including and the other excluding the variable(s) of interest within variable categories, are evaluated in terms of the reduction in the square of the multiple R from the first to the second linear model. In the comparisons made, primary emphasis was placed on the cost of obtaining data for the variable(s) being considered for exclusion relative to its (their) predictive value. Following reduction to a parsimonious set of predictors, stepwise multiple linear regression was used to obtain a final predictive model. This final model was then cross-validated and tested for generality as an additional evaluation of validity across courses.

The final activity in the study was the production of a computer cost analysis program entitled Aid for Instructional Development and Evaluation (AIDE). AIDE is a modification of the Rand cost analysis program MODCOM, Method of Designing Instructional Alternatives (MODIA) (Hess and Kantor, 1976) set of programs. The modification consisted of reprogramming MODCOM to use the predictive model regression equation developed in this study while retaining all of MODCOM's cost analysis features. The program output is a series of tables which describe the course specifications including the student and lesson variable values employed by the predictive model regression equation, resource requirements and costs, and the total course cost. To illustrate its use, the AIDE program was exercised in answering three sample questions related to student characteristics and course design (See Section 5.4).

3.0 DESCRIPTIVE MODEL OF COMPUTER-BASED TRAINING SYSTEMS

Antecedent to the development of the computer-based predictive model, it was necessary to define the scope of the instructional process to be modeled. This was done through the generation of a descriptive model. This descriptive model provided a basis for (a) conceptualizing the overall instructional process, (b) identifying gaps in the conceptualization, (c) identifying variables which could be quantified for inclusion in the predictive model, (d) determining data collection requirements, and (e) assisting in the interpretation of results. What is presented is not intended to represent the only way or the optimal method of accomplishing individualized, self-paced instruction, but rather it is an attempt to represent a generalized model which can encompass a wide variety of computer-based training systems. The descriptive model was developed in two stages. The first stage, essentially the context for the descriptive model itself, is illustrated in Figure 1.

The most basic element defining the characteristics of an instructional process model would appear to be the criterion behaviors to which the student is to be trained - the set of skills assumed to be required in the field. In the Air Force, these skills are rather explicitly defined by the Specialty Training Standard (STS) for each field.

The curriculum, the instructional content of a particular course, represents the interpretation of these behavioral goals by the course personnel. Since the curriculum is defined by the course personnel, it must be assumed that it will be shaped by their cumulative experience, both in the field and in the classroom, and by their knowledge of local institutional constraints, e.g., availability of training devices, usual ratio of instructional personnel to students, and physical plant limitations. The final definition of the curriculum is represented by the course planning documents. For the Air Force, this is the Plan of Instruction (POI). These documents contain an explicit statement of the course content, the amount of instruction (time) to be devoted to each topic, the instructional method (e.g., lecture or demonstration) where available, and the training aids (e.g., films, manuals and actual equipment to be employed). Throughout this study, it

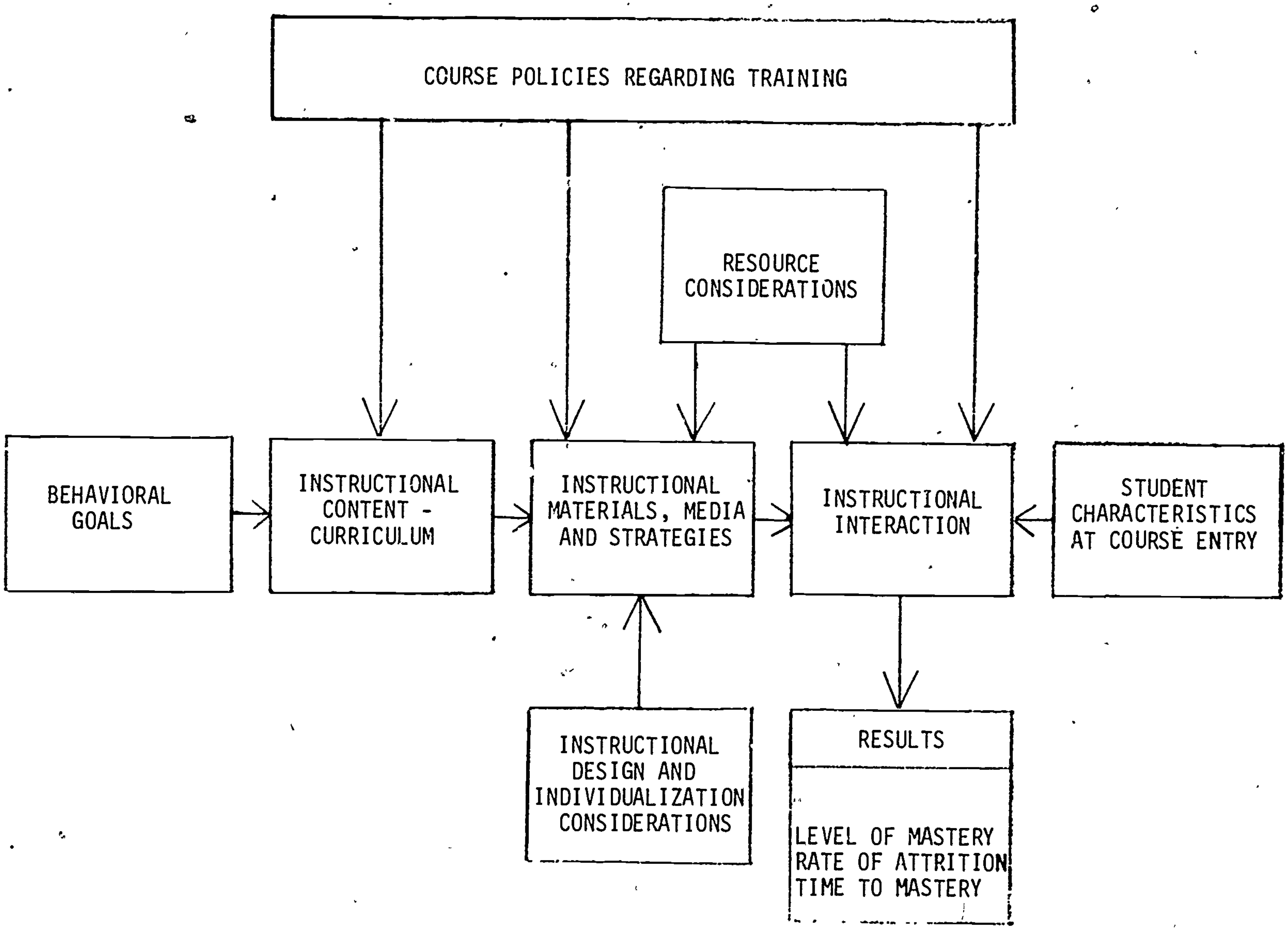


FIGURE 1: General Model of Instructional System Development, Implementation and Evaluation

will be assumed that the course to be modeled is in existence, probably in a conventional, group-paced format, and that course planning documents are available.

Since the purpose of the predictive model being developed is to represent a self-paced, individualized course, it is assumed that in situations in which the model is to be employed, a complete set of instructional materials, representing the entire course content, will need to be selected or developed. Thus, the next block in the diagram represents the means by which the instructional content is to be presented. These are the defining characteristics of the course of instruction to be developed. Is the instructional method to be expository or oriented toward discovery and problem solving? Is the presentation narrative or programmed, that is, frame oriented with embedded questions? If programmed, what is the frequency of interaction? To what extent are pre- and post-organizers, such as objectives and post-questions employed? Is the instruction merely self-paced, or is it individualized in the sense of advanced placement and assignment of alternative instructional treatments? What presentation media are employed, e.g., print, audio-visual, or computer-assisted instuction? As is indicated by Figure 1, these instructional characteristics are a function of several considerations: the content to be taught; explicit decisions regarding instructional design, individualization strategies, and media; the availability of instructional resources; and the influence of institutional constraints and policies. The category of instructional resources is meant to include presentation media (printed materials, audio-visual devices, terminals for computer-assisted instruction), the materials and equipment which the student is being trained to work with in the field (e.g., manuals, actual devices and tools, simulators), and terminals for interacting with a computer-management system.

The instructional interaction, the process through which learning takes place, is primarily a function of the instructional content, mode of presentation, and the characteristics of the students at the time of their entry into the course - the level of their aptitudes and abilities. Although not shown explicitly in Figure 1, student characteristics will, hopefully, have been taken into consideration by the instructional design process and, to the extent necessary, reflected in the course planning documents. It is unreasonable to expect, however, that the instructional presentation will be perfectly matched to student characteristics. There is also the possibility that the average ability level of the students will vary over time as a function of demand for trained personnel and economic fluctuations in the civilian sector. Finally, the total distribution of student characteristics, as well as the average level, must be considered in evaluating the entire training system throughout.

It must be recognized that the nature of the instructional interaction is also shaped by existing course policies. These are, unfortunately, intangible factors concerning the prevailing attitudes among the instructors and their supervisors, and the incentives, positive and negative, explicit and implicit, to which the students are exposed. Finally, the instructional interaction, particularly the time it requires, is directly a function of the actual, day-to-day availability of the instructional and management resources. While resource availability was presumably taken into consideration by the instructional system design, problems may arise if the student entry rate is substantially increased or if equipment maintenance is not adequate. In that case, student queuing for resources can account for a substantial portion of the total training time.

There is undoubtedly a host of measures by which the effectiveness of the instructional interaction, of the total instructional system, can be judged. The most tangible measures, however, are level of mastery, rate of attrition, and time-to-criterion. As will be discussed in subsequent sections of this report, level of mastery is exceedingly difficult to capture in a model intended to generalize across training programs. Since the prime purpose of the predictive model is to provide a tool for the comparison of alternative instructional systems, all of which are criterion referenced, it will be assumed that the required level of mastery is primarily a policy decision that remains constant from one system to another. If level of mastery is indeed fixed, the only two parameters left free to vary are rate of attrition and time-to-criterion. While attrition would appear to be a plausible dependent variable, it has been the authors' experience that, in a miltary training environment at least, it is also largely a function of course policy. Thus, the primary dependent variable to be considered by the model will be time-to-criterion, the time required to complete the course of instruction.

Given the dependent variable of time-to-completion, the next step was to develop a description of the instructional interaction process which would

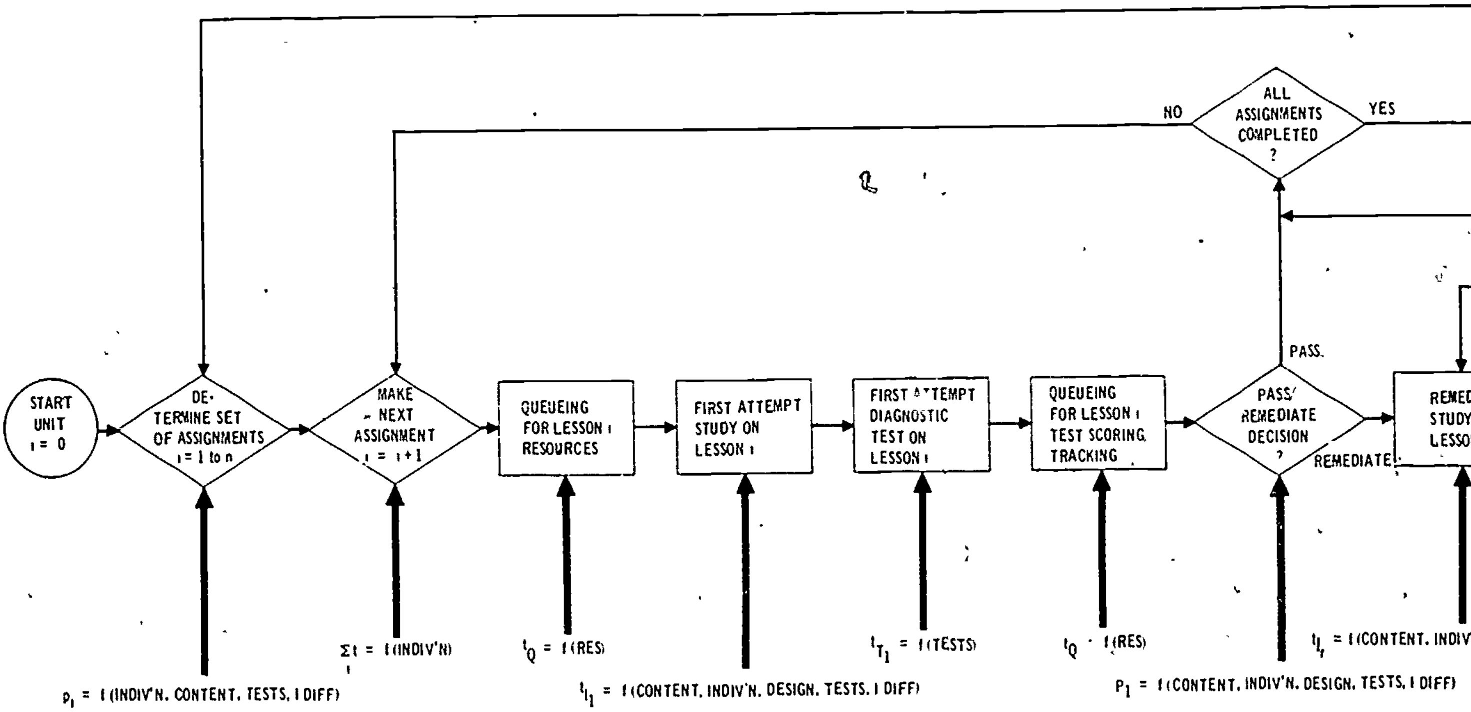
(a) account for time-to-completion, (b) generalize across a variety of computer-based training systems, and (c) incorporate the classes of independent variables outlined in Figure 1 and the preceeding paragraphs. Finally, it was desirable that the model be sufficiently fine grained that each of the individual components of the model could be related to a small subset of the independent variables and that the times attributable to each component sum to equal total time-to-complete the instructional unit. This descriptive model is shown in Figure 2.

A course structure is assumed in which the curriculum consists of one or more major instructional units. Each unit is assumed to end with a criterion referenced examination which the student must pass in order to proceed to the next unit, or, in the case of the last unit, to be graduated from the course. In the descriptive model, this examination has been termed a <u>credentialling test.</u> In Air Force technical training, the corresponding instructional unit is a "Block." Student scores on end-of-block tests are entered in the student's permanent record; a student who meets criterion on the block test is considered to have demonstrated proficiency on the block content, and decisions concerning academic elimination from the course are made on the basis of block test scores and times-to-block-completion. It is assumed that, up to a point, a student failing to pass the credentialling test will be reassigned part or all of the instructional unit and then retested. The descriptive model is intended to account for the time required for a student to complete an arbitrary instructional unit - to reach criterion on the unit credentialling test.

Within each major instructional unit, it is assumed that the curriculum is divided into a number of smaller units, each covering one or more objectives, which will be termed lessons. It is further assumed that, in general, each lesson has a criterion referenced test over the lesson content. Lesson tests are intended to be for diagnostic rather than credentialling purposes. That is, the primary purpose of the diagnostic tests is to track student's progress through the course, to detect specific areas of weakness and misunderstanding, and to provide a basis for lesson level remediation in these areas. Diagnostic test scores would not, as a rule, be made part of the student's permanent record.

Turning now to the components of the model, the first decision point, <u>Determine Set of Assignments</u>, represents a form of individualization which, in

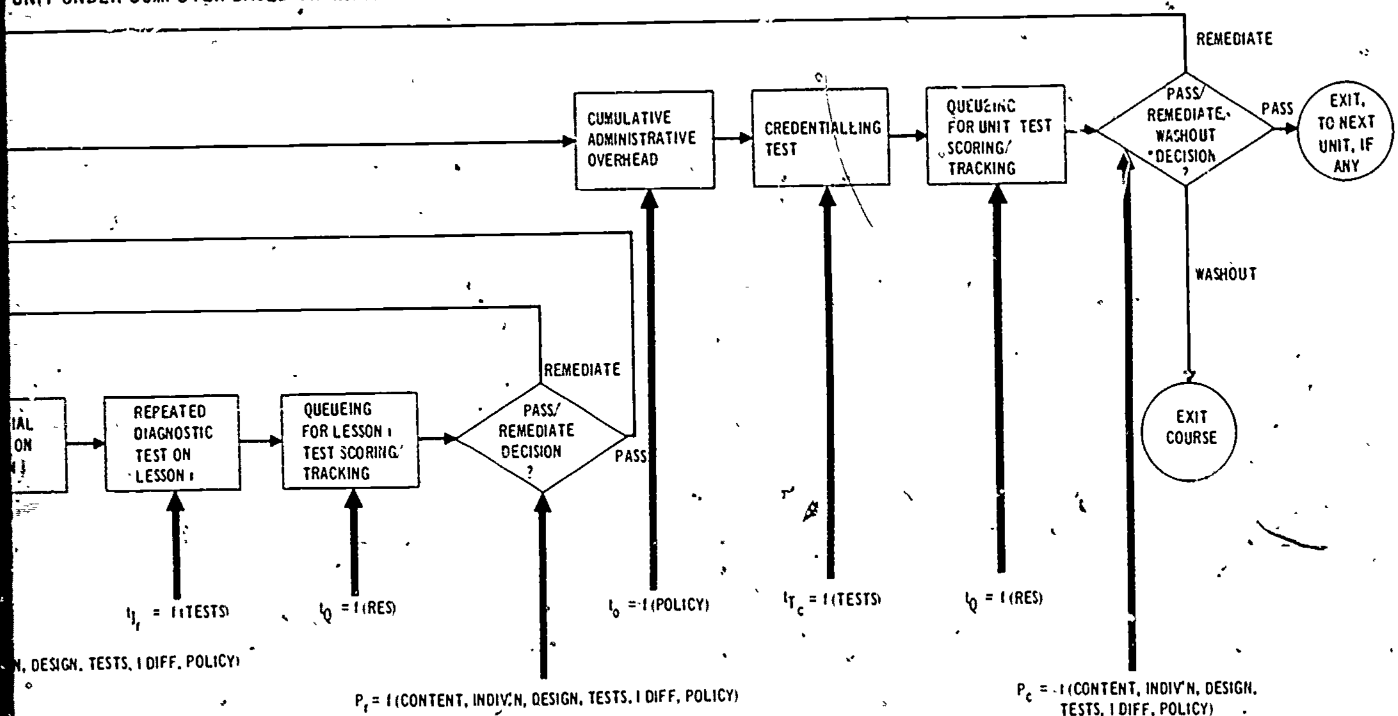
FIGURE 2: DESCRIPTIVE MODEL OF TIME TO COMPLETE AN INSTRUCTIONAL



CATEGORIES OF I

- CONTENT - INSTRUCTIONAL CONTENT
  - QUANTITATIVE MEASURES
  - QUALITATIVE MEASURES
    - CRITERION BEHAVIORS
    - CONTENT CLASSIFICATIONS
- INDIV'N - INDIVIDUALIZATION CONSIDERATIONS
  - PLACEMENT
  - ALTERNATIVE INSTRUCTIONAL TREATMENTS
- DESIGN - INSTRUCTIONAL DESIGN CONSIDERATIONS
  - MEDIA
  - ORGANIZERS
- TESTS - TEST CHARACTERISTICS
  - TYPE OF TEST ITEMS
  - NUMBER OF ITEMS
  - CRITERION LEVEL

UNIT UNDER COMPUTER-BASED TRAINING SYSTEM MANAGEMENT



NDEPENDENT VARIABLES

I DIFF – STUDENT INDIVIDUAL DIFFERENCE CHARACTERISTICS
- APTITUDES
- INTELLECTUAL SKILLS
- PSYCHOMOTOR SKILLS
- AFFECTIVE TRAITS

RES – RESOURCE CONSIDERATIONS
- NUMBER OF TERMINALS
- NUMBER OF INSTRUCTIONAL RESOURCES
- RESOURCE MANAGEMENT

POLICY – COURSE POLICY CONSIDERATIONS

any particular system, may be absent or present and, if present, may be present in varying degrees. It serves two functions. On a student's first pass through the instructional unit, it is analogous to advanced placement - on the basis of known information about the student's abilities and current skills, is it probable that he could skip one or more lessons without seriously jeopardizing his chances of meeting criterion on the credentialling test? Similarly, on a remedial pass through the unit (following failure to meet criterion on the credentialling test), what minimal set of lessons (or partial lessons) can be assigned and still have reasonable assurance that the student will meet the credentialling test criterion on a retest? Within the descriptive model, this component is represented by the probability (p_i) that the student will be assigned a given lesson (lesson i). It is assumed to be a function of the system's capability for individualization, the content of lesson i, the characteristics of the credentialling test, and the student's specific abilities and skills.

The second decision point, Make Next Assignment, is similar in that it also represents a form of individualization which may be absent or present in varying degrees in different instructional systems. It is intended to represent system capability for individualized assignment of alternative instructional treatments at the lesson level. Time savings attributable to this component are represented as being distributed across other components in the model. That is, individualized assignment of alternative treatments will impact both first attempt and remedial study times, the probability of passing the diagnostic tests, and, to an extent, the time required for testing itself.

The next component, Queuing for Lesson i Resources, is the first to represent a time consuming activity, any delay due to the unavailability of lesson resources which the student may encounter prior to being able to start his next assignment. It has lower limit of zero time and is assumed to be a function of both the quantity of available resources of the needed type and the system's capability for resource management, for scheduling assignments so as to avoid resource bottlenecks.

The component entitled First Attempt Study on Lesson i represents the amount of time consumed by the student's initial study of the lesson i content on a given pass through the instructional unit, either his first pass through the unit or unit level remediation. This component accounts for the major portion of the student's first pass time in the instructional unit and is assumed to be a function of the lesson content, system capability for individualization (the availability and individualized assignment of alternative instructional treatments), instructional design and presentation considerations, the known (to the student) characteristics of the lesson i diagnostic test, and the characteristics of the student himself.

3.1 FIRST ATTEMPT DIAGNOSTIC TEST TIME.

The amount of time which the student spends completing the test following lesson i, has a lower limit of zero (representing the case in which there is no lesson i diagnostic test) and is assumed to be a function of the test characteristics. These characteristics include whether the content to be tested is primarily knowledge or involves the demonstration of performance skills, and if written, the type of items (completion, multiple choice, or true-false), the number of items (or number of steps in a performance task), and the criterion level. While it could be argued that the amount of time the student spends on the test is also a function of his level of knowledge, and hence a function of the same factors that influence study time, the simplifying assumption is made, for the sake of parsimony, that these factors make a relatively small contribution to the total variance in testing time. They are taken into consideration in a subsequent component representing the probability that the student will meet criterion on the diagnostic test.

3.2 QUEUING TIME FOR LESSON TEST SCORING/TRACKING.

This represents the amount of time the student must spend, following completion of his diagnostic test, until his test has been scored and he has received his next assignment. Placing this component after the diagnostic test time component implies that testing itself is done off-line. The position of the two components would simply be reversed to represent an on-line testing situation. It is assumed to be a function of the number of terminals available for student/system interaction, the speed with which these interactions can take place, and the extent to which assignment scheduling (resource management) can prevent the occurrence of waves in the level of student demand for terminals.

3.3 PASS/REMEDIATE DECISION

The following decision point represents the outcome of scoring the diagnostic test. the probability that the student has met the test's stated criterion. If so, it is assumed that he proceeds to his next lesson assignment, if any. If not, it is assumed that he is assigned a remedial activity designed to enable him to meet criterion on the previously failed objectives. This probability is assumed to be a function of the content of lesson i, the system's capability for individualized assignment of alternative instructional treatments, instructional design considerations for lesson i, the characteristics of the lesson i diagnostic test, and the relevant characteristics of the student himself. If there is no diagnostic test corresponding to lesson i, the decision would, of course, always be "Pass."

Let us first consider the case in which the student fails to meet criterion on the diagnostic test and is assigned a remedial activity. The bulk of this activity is represented by the component labeled Remedial Study on Lesson i. The amount of time required for this activity is assumed to be a function of the same factors which determined first attempt study time on the lesson and, in addition, course training policy considerations. The intent of including this policy factor is to allow for situations in which the local training policy dictates that the student retest within a certain period of time or that the student spend at least a minimum period of time before retesting.

It will be noted that the component Queuing for Lesson i Resources has not been included in the remedial loop. It is assumed that resource management will be such that if a training device was required for the student's first attempt on the lesson, the device will remain available to him for remediation.

3.4 REPEATED DIAGNOSTIC TEST ON LESSON i AND QUEUING FOR LESSON TEST SCORING/TRACKING

The next two components, are essentially the same, and a function of the same factors, as the comparable components in the loop respresenting initial study. It should be noted that the number of items on the diagnostic test, and hence the time required for testing, could change if a scheme is employed by which a student is retested only over previously failed objectives.

The following decision point, the probability that the student will now meet criterion, is analogous to the prior, first pass decision point and is assumed to be a function of the same factors with the addition of a course policy variable. The introduction of the policy factor is to allow for those situations in which local policy might require that a student proceed to the next lesson assignment after two or three lesson attempts. This might be accomplished, for example, through intensive remediation by an instructor and his certification that the student has met the diagnostic test criterion. If the decision is that the student again failed to meet criterion, it is assumed that he will recycle through the remedial loop. A decision that the student has now met criterion returns him to the same point as was the case for a student who met criterion following his initial attempt on lesson i.

3.5 INSTRUCTIONAL UNIT LEVEL COMPONENTS

If the set of lessons assigned to this student for the current instructional unit has not yet been completed (All Assignments Completed?), he repeats the cycle described in the preceding paragraphs. If all assigned lessons have been completed, that is, if the student has studied all assigned content in the instructional unit, he is assigned the unit credentialling test.

The component shown preceding the credentialling test, Cumulative Administrative Overhead, is intended to account for that time which, while the student was in the current instructional unit, was spent on non-instructional activities. Examples would be roll call, extra group instruction such as safety lectures, classroom clean up, assignment to special details, smoking and coffee breaks. This time is to be strictly a function of local course policy and would have to be estimated in each specific situation.

Time spent completing the credentialling test is assumed to be a function of the same test characteristics as was the case for the diagnostic tests. This component would, however, also include any time spent in critiquing the student's item-by-item performance on the credentialling test, an activity assumed to be unlikely following the more frequent diagnostic tests.

Again, allowance must be made for the time required to complete test scoring. This is represented by the component labeled Queuing for Unit Test Scoring/Tracking and, as was the case for diagnostic test queuing, is assumed to be a function of terminal resource availability.

3.6 PASS/REMEDIATE/WASHOUT DECISION

The final decision point represents the outcome of the evaluation of the student's performance on the credentialling test. If the student is determined to have met the stated criteria, he proceeds to the next instructional unit or is considered to have completed the course. It is assumed that a student who fails to meet criterion will be "washed back" to repeat some or all of the lessons in the instructional unit. For the sake of parsimony, it is assumed that this major, unit-wide remediation can be modeled in the same manner as was the student's first pass through the unit. The amount of material assigned for remediation may differ from the student's first pass through the unit depending on the system's capability for individualization. Finally, it is assumed that the decision to eliminate a student from the course on the basis of academic deficiencies will only be made following a credentialling test.

4.0 PREDICTIVE MODEL OF COMPUTER-BASED TRAINING SYSTEMS

4.1 DESCRIPTION OF DATA SOURCE

4.1.1 Selection Criteria - The criteria established for selecting a data source were as follows:

- o A computer-based, self-paced, individualized instructional system well into its development cycle
- o The availability of quantitative and qualitative course content descriptions from both the prior, conventional mode of instruction and from the current self-paced mode
- o The availability of pre-instructional measures of trainee characteristics
- o The availability of trainee performance (time and score) data under the computer-based system.

Of the available sources, the Air Force Advanced Instructional System (AIS) at Lowry Air Force Base, Colorado, was considered the best to meet these criteria. In addition, resident specialists, familiar with the characteristics and use of the AIS data base were available as consultants. Computer time and a limited amount of software support were also made available.

4.1.2 The Advanced Instructional System - AIS is being developed by the McDonnell-Douglas Corporation under a contract with the Air Force Human Resources Laboratory (TT), Lowry Air Force Base (Rockway and Yasutake, 1974; Yasutake and Stobie, 1975). It is intended to be a comprehensive CMI/CAI system for the administration and management of large scale, individualized technical training. At the time of this study, four courses, containing approximately 600 students, were being supported with the overall goal of achieving an average 25 percent reduction in training time over what was required prior to system implementation. These four courses represent a wide range of learning requirements, from clerical to mechanical to problem solving skills, and cover a variety of course administrative requirements. In addition, AIS serves as a research and development tool to allow evaluation of a variety of innovations in instructional technology, particularly those aimed at the adaption of instruction to student individual differences.

A large, central computer (CDC Cyber 73-16) provides data processing capability. Data input and output are supported by two types of terminals. A management terminal (consisting of a form reader, printer, and minicomputer enclosed in a console) is used to read and score test forms, transmit data to the central computer, and print out student prescriptions and management reports. An interactive terminal (consisting of a plasma display and keyboard) is used for instructor and course author interaction with AIS data files and will also be used for on-line, adaptive testing and CAI.

The system was designed to provide the functions of diagnosis of student performance, forward-going assignment prescriptions, resource allocation and scheduling, guidance and counseling, information retrieval, report generation, and support for evaluation and research. The software to support these functions comprises the Adaptive Model and Applications Programs component of the AIS. This software was tested and implemented in all four courses during the summer of 1976.

The Adaptive Model contains the component entitled Adapter which assesses cognitive and affective student traits and states, and selects instructional alternatives that best match the needs of each student at each node of the instructional sequence. The individualization afforded by the Adapter is constrained by the prerequisite relationships inherent in a course structure and by the availability of instructional resources. Thus, a Resource Allocation/Scheduling Model within the adaptive model maintains the inventory of available resources, restricts the assignment of alternatives to the available resources, supports the scheduling of team tasks, and attempts to optimize the utilization of expensive and limited training resources.

Both the Adapter Model and Resource Allocation/Scheduling Model operate on predictions as to the amount of time each student will require to complete his current assignment and his current course unit. These data, in conjunction with predictions of student scores on each criterion test, are used to provide the guidance and counseling function in that each student's performance is continually evaluated relative to other students.

At the time this study was being conducted, the AIS was operating in a more rudimentary mode, termed Initial CMI. Although the courses were self-paced, the primary means of instruction was limited to programmed textbooks. Instructional alternatives were under development, but only a very few had been integrated into the courses. While the main track of instruction did include some instances of audio-visual lessons, the number and variety of these lessons were insufficient for the purposes of this study. While the system provided test scoring and data recording capabilities, the sequence in which the lessons were studied and the assignment of instructional resources were under the control of the classroom instructors. Each student recorded the amount of time he spent in various activities, e.g., first-attempt-lesson-study, remedial study, and testing, on his individual test answer sheets. These data were recorded by the system, but there was no direct measurement of these times.

4.1.3 Courses Selected - The four courses supported by AIS at the time of the study were Inventory Management Specialist, Materiel Facilities Specialist, Precision Measuring Equipment Specialist, and Weapons Mechanic. The analysis to be conducted required a large data base (hence a relatively large student flow) and a large overlap between the content ~~of~~ the current, self-paced course and the earlier, conventional course. On the basis of these considerations, the two courses selected for modeling were Inventory Management Specialist (IM) and Weapons Mechanic (WM).

Under conventional instruction, IM was a 210 hour course leading to the Air Force Specialty of Inventory Clerk. Course content primarily concerns inventory procedures, record keeping, and shipping. The work requires clerical and procedure-following skills. The selection criterion for admission is a percentile score of 60 on either the General or Administrative Scale of the Armed Services Vocational Aptitude Battery (ASVAB) given all enlisted personnel at the time of induction.

Under conventional instruction, WM was a 540 hour course leading to a specialty in weapons handling. The course teaches the cognitive and psychomotor skills required to handle and load air-to-air and air-to-ground weapons and to troubleshoot and repair related equipment. A key feature of the WM course is its employment of team concepts in skill development. The admission criterion is a percentile score of at least 60 on either the Electrical or Mechanical scales of the ASVAB.

Both courses were divided into a number of "blocks" (six in IM; 12 in WM), each approximately a week in length. Each block contained from 10 to 30 lessons and an end-of-block test. Students were required to meet criterion on these block tests before proceeding to the next block. Under AIS, lessons are approximately one to two hours in length; each covers two or more instructional objectives, and most conclude with a diagnostic lesson test. Under conventional instruction, the lessons had tended to be longer, and, as a rule, a conventional lesson was broken up into two or more AIS lessons.

Of the six blocks in the IM course, the first five were analyzed for this study. Insufficient student performance data were available from the sixth since it had recently undergone a major revision. The last four of 12 blocks were analyzed in the WM course. The course was being implemented under AIS from back to front, and insufficient data were available from the lower numbered blocks.

4.2 DEFINITION OF VARIABLES FOR ANALYSIS AND DATA COLLECTION PROCEDURES

4.2.1 Definition of Criterion Variable - Several types of time data available from AIS were considered for use as the criterion variable to be predicted by the model. These included block completion time, first pass block time, lesson completion time, first attempt lesson time, first attempt study time, and first attempt test time. Of all of these time criteria, block completion time was considered to be the most useful criterion and, because of its relationship to the descriptive model, the most appropriate. It was, therefore, selected as the criterion variable to be predicted by the model.

For purposes of developing the predictive model, however, the number of blocks was too small to provide sufficient variability in content. Time prediction equations needed to be developed at the lesson level. As was noted in the discussion of the descriptive model, it could not be assumed that the sum of lesson completion times would equal block completion time or even first-pass block time. Each pass through the block also includes the time required for the block test itself, cumulative administrative overhead which included student "breaks," and time lost due to queuing for resources and test scoring. No accurate time data were available for any of these components. The most appropriate approach, therefore, appeared to be one in which the variable predicted would be lesson completion time. A proportional "lost time" estimate, determined from the discrepancy between the sum of lesson completion times and block completion time, and assumed to contain the time allocated to block remediation, overhead, and queuing would then be employed to provide an estimate of block completion time.

It was found, however, that lesson completion time was itself extremely unreliable. The time required for each attempt on the lesson was recorded on a separate test answer sheet with an identifying attempt number. Because of the multiple pieces of paper involved and because procedures were not always rigidly adhered to in the classrooms, the problems of incomplete and missing data were widespread. The amount of available lesson completion time data which could be considered reliable was inadequate for the modeling study.

Some consideration was given to the separate prediction of reported first-attempt-study and first-attempt-test time. This approach was discarded, however, since there had been a continual problem in instructing students in how to differentially record study time and test time due to confusion over self-tests which were to be counted as part of study time. The variable finally selected to serve as the criterion to be predicted was <u>first-attempt-lesson-time</u>. This variable was based on a simple start and stop time recorded on the student's answer sheet and had been found to be the most reliable of the various time measures. For the majority of cases, it was equivalent to lesson completion time. It could be related to block time by increasing the magnitude of the proportion of "lost time." Viewed in the context of the Descriptive Model (Figure 2), the criterion measure was the cumulative time (across lessons) attributable to the two components entitled <u>First Attempt Study on Lesson i</u> and <u>First Attempt Diagnostic Test on Lesson i</u>.

The prediction of block and lesson test scores presented a very different problem - that of generalizability. It was intended that the predictive model to be developed should generalize across a variety of technical training courses. While there is no ambiguity concerning the meaning of a clock hour and no variation in the meaning of this concept from one course to another, this is not the case with regard to test scores. The probability that a given student will obtain a passing score on an arbitrary test is at least as much a function of test item difficulty as of the student's characteristics and the content being tested. Item difficulty is, in turn, primarily a function of the experience and opinions of the developers of the specific instructional materials and the test. It is a safe assumption that the foremost factor influencing a test developer's decisions regarding item difficulty and adequate criterion performance is his past experience with the performance of students in this particular course of instruction. Thus, while it appeared implausible to generalize across courses with respect to expected test score or expected failure rates, it did appear reasonable to expect that the level of student performance would remain relatively constant from conventional to self-paced, individualized instruction. This assumption was made explicit in the predictive model being developed. That is, it was assumed that the level of within-course student performance, the skill level of the course graduates, and the rate of attrition would remain unchanged following the transition from conventional to self-paced, individualized instruction. The only dimension left free to vary was, therefore, time.

4.2.2 Definition of Predictor Variables - The variables selected for investigation as potential predictors of first-attempt-lesson time will be discussed in terms of the categories of independent variables influencing the instructional interaction which were outlined in Figure 2 and discussed in Section 3.0.

While it would have been plausible to consider bahavioral goals (see Figure 1) as a category of predictor variables, it was considered more appropriate to obtain measures of the instructional content itself, the course curriculum. Information regarding both classes of factors were available - the Specialty Training Standard (STS) reflecting goals and the Plan of Instruction (POI) reflecting content. While the information provided by the STS is more basic and less subject to change, the relationship between the two documents should remain constant unless the course goals and content are subjected to the type of reanalysis called for by an Instructional System Development (ISD) exercise (U.S. Army Training and Doctrine Command, 1975). The purpose of the predictive model is to examine the effects of self-pacing and individualization, not the effects of ISD. It was therefore assumed that content, as reflected in the POI, would remain constant during the transistion from conventional to individualized instruction. Use of the POI as the reference document for course content has the further advantage of reflecting the influence of local training policy. The specific information derived from the POI is described in paragraph 4.2.2.1.

As we discussed in paragraph 4.1.2, the Initial CMI mode of operation, which was in effect at the time of this study, did not include computer controlled individualization of the type required by the descriptive model, i.e., advanced placement and assignment of alternative instructional treatments. Therefore, no variables pertaining to this factor could be included in the predictor set.

In the category of instructional design considerations, it was not feasible to include alternative media characteristics as predictors because of the limited number of lessons employing media other than text. The extent to which advance, embedded, and post-instructional organizers were present in various lessons did provide a basis for defining a number of predictors. These are discussed in paragraph 4.2.2.2. Predictors in the test characteristics category are discussed in paragraph 4.2.2.3. In addition, a variety of measures of pre-instruction, individual student difference characteristics was investigated. These are described in paragraph 4.2.2.4.

While the quantity and quality of instructional and management system resources have a definite effect on the characteristics of the instructional interaction, particularly the time required for its completion, there was not sufficient variability in this factor among the various AIS courses to permit its use as a predictor variable. Consequently, the predictive model assumes an "adequate" supply of resources.

It was recognized that course policy regarding training has a pervasive influence on the instructional interaction. It is by nature, however, course-specific and relatively intangible. For this initial attempt at model development, therefore, it was considered necessary to ignore this factor - to consider its effect as contributing to unaccounted for variability except in-so-far as course policy influences were reflected in the instructional content.

4.2.2.1 Course Content Variables - Course content characteristics were determined from descriptions contained in the plans of instruction (POI) pertaining to the five IM and four WM blocks to be analyzed. Each of the Armed Services has planning documents containing detailed descriptions of lesson objectives and the distribution of lesson time into categories such as lecture, performance, testing, and outside assignment. The variables selected to describe each lesson were based on information common to these planning documents.

The content of each AIS lesson was identified in the POI on the basis of common objectives. In some cases, the set of objectives covered by a single conventional lesson had been transferred directly to an AIS lesson. In general, however, the conventional lessons were longer than AIS lessons and contained more material. In these cases, two or more artificial conventional lessons were defined, each containing the objectives corresponding to a single AIS lesson. The total instructional time in the conventional lesson and the time allocated to each of the instructional methods by the POI were then distributed across the new, artificial lessons on the basis of the objectives contained in each new lesson. In a similar fashion, if an AIS lesson contained the objectives of two or more conventional lessons, the times within the POI categories were summed to create an artificial conventional lesson. If the depth of content in the conventional lesson had been reduced or increased in the corresponding AIS lesson, the POI times were increased or reduced, by category, by the corresponding amount. Finally, there were some cases in which course content had changed during the AIS implementation period, and no conventional instruction POIs were available which included the new objectives. When this occurred, the AIS lesson containing the new objectives was dropped from the analysis.

These decisions and translations were made by members of the AIS materials development teams and content matter specialists who, in many cases, had previously taught in the conventional courses. The conclusion of this exercise defined a set of AIS lessons in the nine blocks which could be characterized by descriptive statements in actual POIs or in POIs constructed artificially.

It was obvious that one of the most promising predictors of first-attempt-lesson time under a self-paced system would be the amount of time devoted to that lesson under conventional instruction. This variable was defined as total POI time. There was reason to expect, however, that predicted first-attempt-lesson times (hereafter referred to simply as lesson time) would be more accurate if separate variables were defined for the various categories of instruction outlined by the POI. Four such variables were defined: Lecture/Discussion; Demonstration/Performance; Programmed Instruction/Audio-Visual; and, Outside Assignment.

Each AIS lesson contained only material which pertained directly to the stated objectives. The "nice to know" information which would usually be included in a lecture had been eliminated. Therefore, it was assumed that the amount of time which the POI allocated to lecture and discussion activities would be shortened dramatically under self-pacing.

Under conventional instruction, Demonstration/Performance activities usually involve at least two repetitions of the task to be performed - once by the instructor and once by the student. Under self-pacing, the task was performed only once by the student under step-by-step guidance by the instructional materials. This might be slower or faster than was the case under conventional instruction.

Analysis of the objectives, taught at least in part through Demonstration/Performance activities, suggested that a further breakdown might be profitable. While some of the objectives were primarily psychomotor in nature, others appeared to be primarily cognitive in nature (e.g., troubleshooting). Therefore, two subcategories were defined: Demonstration/Performance-Cognitive; and Demonstration/Performance-Psychomotor. While the distinction could have been made on a judgemental basis, an alternative approach was employed. Each AIS lesson could, potentially, contain a performance check, supervised by an instructor, as well as a multiple-choice test. If the AIS materials developers had seen fit to include a performance check in the lesson, the POI Lecture/Discussion time was categorized as Psychomotor. Otherwise, the time was categorized as Cognitive.

POI instructional time allocated to programmed instruction or an audio-visual presentation was grouped under a single variable on the assumption that the time required for such activities under self-pacing would not be shortened substantially. Finally, Outside Assignment time was treated separately on the assumption that such activities would be less efficient than if they were conducted in the classroom.

In summary, six quantitative measures of content were defined: The number of minutes allocated by the POI to (a) Lecture/Discussion, (b) Demonstration/Performance-Cognitive, (c) Demonstration Performance-Psychomotor, (d) Programmed Instruction/Audio-Visual, (e) Outside Assignment; and (f) the total number of minutes allocated to the conventional lesson, the sum of the first five measures.

Defining measures of the qualitative characteristics of the content presented a substantially different problem. While several investigators have offered their views regarding the interaction of specific content characteristics and student performance, no one to date has been able to measure the relationship between the content characteristics and rate of learning in an operational environment. The current study employed two distinct approaches to the problem of content classification and conducted a comparative evaluation of the two. The results of this evaluation are discussed in paragraph 4.3.3.1.

The first approach, which will be termed content classification, concentrated directly on the lesson content as described by the POI. Three broad categories were defined: memory, cognitive, and psychomotor. While few attempts have sought to identify such broad categories (most have dealt with more specific factors in well defined environments, e.g., Guilford, (1971), it was thought that this approach would have greater utility to instructional personnel given the task of characterizing course content.

There was a dearth of personnel qualified and available to evaluate each lesson in terms of the percent (later translated into minutes) of memory, cognitive, and psychometer content involved. For the IM course, two instructors and a third party, not a subject matter expert, were asked to make these ratings jointly on the 29 lessons of interest. Only one subject matter expert was found to make these evaluations for the 35 lessons of interest in the WM course. For each content area represented in these lessons, the raters were asked to judge on a scale of one to five how simple or complex the material appeared to be for the trainee population to whom it was presented. For example, the content of a particular two hour lesson might be judged to be 15 percent (18 minutes) memory and 85 percent (102 minutes) psychomotor. The memory content might be judged as being difficult and given a complexity rating of five. The psychomotor component of the lesson might be judged to be of medium complexity and given a rating of three. Since the lesson was devoid of cognitive material, no rating was required for that category. The precedure of obtaining content ratings for the IM and WM lessons, either by inter-judge agreement or by a single judge, respectively, made the determination of inter-judge reliability estimates inappropriate.

Definitions and examples of the three categories and of the complexity scales within each category are provided in Table 1. These same definitions were given to the raters to guide their review of the POIs. These ratings served as input to the data base.

The second approach to categorizing lesson content adopted a more conventional method, more oriented toward the terminal behavior described by the objectives stated in the POI. A modification of Merrill's (1972) classification scheme was adopted. Merrill's categories of discriminated recall, classification, rule using, and higher order rule using were supplemented with the category of psychomotor tasks. A binary easy/difficult dimension was then added to each category. Definitions of the five categories and the bases for the easy/difficult decisions are shown in Table 2.

Two psychologists on the AIS project staff classified each objective listed in the relevant portions of the POIs into one of these ten categories. Each lesson was then rated on the basis of the proportion of the content attributable to the objective(s) in each category. For example, a particular lesson might contain four specific performance objectives. Three of the objectives might be classified as Discriminated Recall. Two of these might be judged as Discriminated Recall - Easy and the third, Discriminated Recall - Difficult. The fourth objective might be categorized as an easy classification task. The POI time allocated to the two easy discriminated recall objectives would be assigned to the variable, Discriminated Recall - Easy, for this lesson. The time attributable to the other two objectives would be the values of the variables, Discriminated Recall - Difficult and Classification - Easy. The variables representing the seven remaining categories of terminal behavior or performance, Classification-Difficult through Psychomotor-Difficult, would be given values of zero.

TABLE 1

CONTENT CLASSIFICATION: DEFINITION AND METHOD OF CALCULATION

CONTENT AREA	DESCRIPTION
Memory Related Content	That portion of the lesson content requiring retention of information. Measured in terms of the minutes of conventional instruction.
Memory - Simple/Complex	A five point rating of the simplicity or complexity of the memory related element in the lesson. Simple memory content (one) includes recognition of familiar terms; complex memory content (five) includes recall of many new technical terms.
Cognitive Content	That portion of the content related to knowledge gathering, understanding relationships and principles, and problem solving. Measured in terms of minutes of conventional instruction.
Cognitive - Simple/Complex	A five point rating of the simplicity or complexity of the cognitive element in the lesson. Simple cognitive content (one) involves procedure following, labeling, and information collecting. Complex cognitive content (five) involves symbol manipulation, problem solving, decision making, and evaluation.
Psychomotor Content	That portion of the content related to performance or "hands-on" tasks and involving manual dexterity, eye-hand coordination, or gross motor movements measured in terms of minutes of conventional instruction.
Psychomotor - Simple/Complex	A five point rating of the simplicity or complexity of the performance element. Simple psychomotor content (one) includes gross motor movements. Complex psychomotor content (five) involves fine motor dexterity, complex eye-hand coordination, and precise motor movements.

TABLE 2

BEHAVIOR CLASSIFICATION DEFINITIONS

BEHAVIOR CATEGORY	DEFINITION
Discriminated Recall-Easy Difficult	Given a symbol, object or event, a student responds by providing the associated member of the response set. If the number of members in the stimulus set was large and/or if the members of the response set were unfamiliar (e.g., new technical terms), the objective was judged to be difficult.
Classification-Easy/Difficult	Given a new example from a class of items, a stud^nt responds with class membership. The easy/difficult dimension was based on the number of classes.
Rule Using-Easy/Difficult	Given a new experience, a student applies a rule (a set of operations) to produce the appropriate members of the response set. Rule Using-Easy was essentially following written procedures (e.g., technical orders). Rule Using-Difficult was following procedures in the absence of written guidance.
Higher Order Rule Using - Easy/Difficult	Analogous to problem solving activity, the retrieval or generation of rules by applying a higher order rule to determine problem class membership. The easy/difficult dimension was based on the number of steps in the problem solution.
Psychomotor-Easy/Difficult	The performance of fine or gross motor control movements to accomplish a task. The easy/difficult dimension was based on the familiarity or novelty of the task components.

The psychologist raters, although familiar with the AIS courses, were by no means subject matter experts. Therefore, their ratings were checked and, in a few cases, modified, by members of the course materials development teams. This procedure was undertaken as an attempt to provide at least face validity for these ratings. Since independent ratings of the objectives were not obtained, interrater reliability estimates could not be generated.

4.2.2.2 Instructional Design Variables - As was previously discussed, AIS, at the time of this study, included insufficient examples of lessons taught by media other than programmed texts to include alternative media as variables in the predictive model. A similar situation existed with respect to alternative instructional treatments designed to compensate for specific deficiencies. Instructional design considerations were, therefore, limited to "organizers." Organizers were defined as "assists" provided in the instructional material to enhance the trainee's achievement of a behavioral objective.

The most prevalent type of organizers in the AIS materials was the list of objectives at the beginning of each lesson. Since every lesson included such a list, there was no variability across lessons with respect to this factor; and it was, therefore, of no value as a predictor variable.

Two other types of organizers were present which did vary from one lesson to another - embedded questions and self-check items. With the exception of those lessons which were strictly performance oriented, embedded questions were scattered throughout the textual material. Each consisted of a multiple-choice item, the correct answer to which was provided on the last page of the lesson. The majority of the AIS lessons, again excluding performance lessons, included a self-check item to be completed following study of the lesson but prior to the lesson test. These items were also multiple-choice. The student marked his response on chemically treated paper which then revealed whether or not the response was correct.

The number of embedded questions and the number of self-check items were recorded for each of the AIS lesson analyzed. If no items of particular type were present, a zero was recorded. Although this information was taken directly from existing AIS lessons, a tactic which would not be possible if the model were actually being used to predict the characteristics of a self-paced course yet to be constructed, the number of embedded and self-check items was assumed to reflect instructional design policies which could and should be established prior to actual materials development.

4.2.2.3 Test Characteristics - Consideration of test characteristics was limited to the lesson tests themselves. Due to the inclusion of new material in the AIS lessons, there were no examples of complete blocks. Thus, all of the block tests included some items from lessons which were not sampled for this study.

Three test characteristics were measured for each lesson test. For each lesson which included a multiple-choice test, the number of test items and the test criterion (expressed as a percentage) were recorded. For lessons without multiple-choice tests, a zero was recorded for both number of items and criterion. For each lesson which included a performance test, a situation in which the student was to perform a task to the instructor's satisfaction, the number of specific checkpoints in the performance task was recorded. Again, a zero was recorded for this variable if the lesson did not include a performance test.

4.2.2.4 Student Characteristics - The variables chosen as student characteristics were determined o :he basis of (a) the ease with which they could be obtained in a variety of military training environments, (b) how representative they were of a wide variety of individual differences, both cognitive and affective, and (c) their known relationship to the prediction of AIS training time criteria in different types of training courses. Thus, the resulting student characteristic variables include the four primary composite scores from the Armed Services Vocational Aptitude Battery (ASVAB), sex, and selected affective and cognitive variables which were common to the AIS pre-assessment batteries of both the IM and WM courses.

A complete description of each of the selected student characteristic variables is presented in Table 3. The variables are organized in three categories: (a) Armed Services Vocational Aptitude Battery (ASVAB) Variables and sex; (b) Cognitive AIS Pre-Assessment Battery Variables; and (c) Affective AIS Pre-Assessment Battery Variables. Wherever applicable, the references for a particular measure of student characteristic variables are cited.

TABLE 3

STUDENT CHARACTERISTIC VARIABLES

VARIABLE CATEGORY	VARIABLE NAMES	DEFINITION
I. ASVAB Composites and Sex	ASVAB Scores: General Ability, Electrical Ability, Administrative Ability, Mechanical Ability	A standard vocational aptitude battery, administered to all enlisted inductees, which contains four primary composite scores for general, electrical, administrative, and mechanical abilities, respectively.
	Sex	An identifier of individual differences in training times attributable to sex differences, where males = 1, and females = 0.
II. Cognitive AIS Pre-Assessment Variables	Reading Vocabulary Test - Total Scores	A 45-item measure of students' ability to recognize the definition of terms frequently used in Air Force documents (Diegnan, 1973).
	Reading Skills Scales 1 and 2	Course-specific measures of students' reading comprehension and speed on materials extracted from IM and WM technical manuals. Scales 1 and 2, consisting of 10 items each, differ only in terms of difficulty, with longer passages and more rigid time limits imposed on Scale 2 (McCombs, 1974).
	Concealed Figures Test	A 20-item measure of students ability to make perceptual distinctions by recognizing which of five simple geometrical figures is embedded within a complex pattern (Diegnan, 1974).
III. Affective AIS Pre-Assessment Variables	Pre-Course State Curiosity Scale	A 20-item self-report measure of students' anticipated feelings of interest in learning the IM or WM course materials (Leherissey-McCombs, 1971).
	Pre-Course State Anxiety Scale	A 20-item self-report measure of students' anticipated feelings of tension or apprehension about learning the IM or WM course materials (Spielberger, Gorsuch, & Lushene, 1970).

TABLE 3 (cont.)

STUDENT CHARACTERISTIC VARIABLES

VARIABLE CATEGORY	VARIABLE NAMES	DEFINITION
III. Affective AIS Pre-Assessment Variables (cont.)	Test Anxiety Questionnaire	A 16-item self-report measure of students' tendencies to become anxious when taking ability or achievements tests (Sarason, 1958).
	Internal-External Scale	A 29-item self-report measure of students' tendencies to feel in control of events versus controlled by external events (Rotter, 1966).
	General Media Preference and Instructional Experience Subscales: Audio Preference; Visual Preference; Printed Preference; Experience with Conventional Institution; Experience with Self-Paced Instruction	A 15-item self-report scale, consisting of five subscales which measure students' general preference for audio versus printed materials, as well as their reported degree of experience with conventional versus self-paced instruction (McCombs, 1974)

The primary rationale for the selection of the four ASVAB variables and sex was that these variables are easily obtained on enlisted trainees in all branches of the military services. In addition, many years of systematic research with the ASVAB battery has shown it to be a highly reliable and valid measure of individual differences in vocational aptitudes. A number of research studies, as well as our own experience with AIS data, have shown sex to be related to individual differences in training times.

Within the Cognitive AIS Pre-Assessment Battery Variables category, three reading ability measures and one perceptual reasoning ability measure were chosen. The reading variables have been shown to be highly predictive of independent variance in training time criteria in each of the four AIS courses. In addition, it was felt that, even though these particular reading measures might not be available in other military applications, similar reading vocabulary, comprehensive, or speed measures were likely to be available. The perceptual reasoning variable, defined by scores on the Concealed Figures Test, was selected on the basis that it was available for both IM and WM students, and it represented a perceptual/reasoning ability that would be generally related to student performance in a variety of technical specialties. At the time this variable was selected, preliminary AIS data indicated that it was moderately related to training times on some of the IM course materials.

The particular measures chosen with the Affective AIS Pre-Assessment Variable category were chosen on the basis of (a) their known relationship to AIS training time criteria; (b) the wide range of student motivations, attitudes, and learning style preferences they represented; and (c) their availability as common predictor variables in both the IM and WM courses. For example, state curiosity, state anxiety, and test anxiety have all been shown to be highly predictive of AIS training time criteria (McCombs and Siering, 1976). Although at the time of this study not much AIS data were available of the Internal-External Scale, it was judged to be a student characteristic variable that would be expected to be highly related to student training times in self-paced instructional environments. Similarly, students' preferences for audio versus visual printed instructional modes of learning, and their experience with self-paced versus conventional instruction were also judged to be important affective predictor variables in self-paced instructional environments.

4.2.3 <u>Creation of Files for Data Analysis</u> - Creating the data files was a lengthy process which involved merging three distinct classes of data:

- o Student data available from the AIS data analysis system: Course; Social Security Number (used by AIS as an ID); sex; preassessment test data; block and lesson number; module number (i.e., instructional alternative type); first-attempt-lesson time; and first-pass-block time
- o Supplementary student data: The ASVAB General, Electrical, Administrative, and Mechanical scores
- o Lesson characteristic data: the POI derived quantitative measures; content classification measures; behavior classification measures; instructional design measures; and test characteristic measures.

Student data were extracted from AIS files representing the nine blocks of the two courses using the AIS Data Extraction Program (DEP). It was necessary to extract data from separate and distinct time periods in order to avoid time periods in which the courses were undergoing substantive changes. The product of this activity was nineteen separate files.

ASVAB scores were not normally recorded in the AIS files since they were not usually available early enough in the course to be of value as predictors. For purposes of this study, however, ASVAB scores were obtained from Air Training Command's Training Management Information System (TRAMIS) for as many of the students as possible represented in the DEP files described above. The scores were obtained on cards, input into the computer, and an additional file was constructed.

A total of 64 lessons was sampled. Twenty-nine of these were from the IM course; six from block one; six from block two, six from block three, four from block four; and seven from block five. The remaining 35 were drawn from the WM course: nine from block nine; eight from block ten; ten from block eleven; and eight from block twelve. Lesson characteristic data were punched on cards, input, and a file was created for each of the nine blocks.

A special purpose program was written to merge files across categories. Each run of this program produced a file containing all relevant data for each of the nineteen DEP files previously created. These nineteen files were then merged into a single tape file containing approximately 13,700 records where each record represented a particular student's first attempt on a lesson of known characteristics. That is, each record contained the relevant characteristics of both the student and the lesson as well as the time required for his first attempt on the lesson.

The magnitude of this file made its retention and manipulation on a disk impractical. The study required two comparable samples, one for regression equation generation and a second for equation validation. Therefore, the file was immediately split into two samples on the basis of whether the final digit of a trainee's Social Security Number was odd or even. After excess records had been deleted from the larger sample, each sample contained 6849 records.

Missing and incorrect data were rampant throughout the developing AIS data base. Typical problems included preassessment forms which were incorrectly read by the system's optical scanner, and trainees who were enrolled without completing any of the preassessment tests. ASVAB scores obtained from TRAMIS were often incomplete or missing entirely. First-attempt-lesson-times contained a small but persistent number of widely deviant values. The primary cause of these outliers was miscoding, e.g., if a student worked on a lesson during two consecutive days, the number of days was often mismarked on the test answer sheet. The measure of first-pass-block-time was also error prone. It was defined as the elapsed time from starting the first lesson in the block until the block test was completed. Errors such as mismarked dates often made this value fallacious.

To reduce these errors as much as possible, sets of constraints were established for these variables. Preassessment scores were recoded as missing values if they were actually missing or exceeded the known limits of the test scores. All ASVAB scores, if present, were determined to be reasonable. First-attempt-lesson-times were limited to a range of fifteen to three-hundred minutes. This eliminated approximately five percent of the data from either end of the distribution. Block times were excluded if the reported time was not greater than the sum of the first-attempt-lesson-times or if the reported time fell outside the range established as reasonable by prior experience with AIS.

The regression analyses was conducted using the (SPSS) Statistical Package for the Social Sciences (Nie, Hull, Jenkins, Steinbrenner, and Brent, 1975). SPSS offers two options with regard to missing data: "pair-wise deletion" which includes all of the data points available for a particular variable in the analysis, and "list or case-wise deletion" which excludes any case from consideration if that case has one or more missing data points in any of the variables included in the analysis. Although the former option is less expensive in terms of lost data, it tends to result in fallaciously high correlation coefficients. Therefore, the case-wise deletion option was selected. This reduced Sample One, the data base to be used for regression equation generation, to 2974 cases, each having a complete set of data points for each variable. It should be noted that this figure does not represent 2974 different students. Varying numbers of observations were generated by individual students. For example, data generated by a particular IM student might be present for the data base for three lessons in Block One and two lessons in Block Two. The implications of these repeated measures are discussed in paragraph 4.3.1 below.

A summarizing list of the variables investigated, their means and standard deviations (based on the final 2974 cases), and their correlation with the criterion variable is shown in Table 4. Given the size of the sample, first order correlations equal to or greater than $R = \pm .05$ are significant ($p < .05$).

4.3 STATISTICAL ANALYSIS AND RESULTS

4.3.1 Description of Statistical Methods - The data were analyzed using several statistical methods, primarily programs from the Statistical Package for the Social Sciences (Nie et al 1975). Available SPSS regression program options were used to constrain data values to reasonable limits and to screen out missing data. The two primary methods employed in obtaining the final prediction equation were linear model comparisons (Ward and Jennings, 1973) and stepwise multiple regression analysis.

In linear model comparisons, two linear models (i.e., regression equations) are compared in terms of the reduction of the multiple correlation coefficient squared (R^2). The model with the larger number of predictors is referred to as

TABLE 4

MEANS, STANDARD DEVIATIONS, AND FIRST ORDER CORRELATIONS OF PREDICTOR AND CRITERION VARIABLES

VARIABLES	MEAN	STD. DEV.	R WITH CRITERION
COURSE CONTENT VARIABLES			
Quantitative Measures (from POI)			
Lecture/Discussion Minutes	89.54	97.58	.489
Demonstration/Performance Minutes - Cognitive	55.70	64.45	.488
Demonstration/Performance Minutes - Psychomotor	27.91	63.19	-.294
Programmed Instruction/AV Minutes	8.43	38.67	.047
Outside Assignment Minutes	51.27	127.10	.029
Content Classification Measures			
Memory Content Minutes	68.86	71.99	.321
Simple/Complex Memory Rating (1-5)	2.61	0.74	.201
Cognitive Content Minutes	145.67	147.37	.329
Simple/Complex Cognitive Rating (1-5)	2.81	1.05	-.015
Psychomotor Content Minutes	20.95	53.13	-.084
Simple/Complex Psychomotor Rating (1-5)	1.23	1.90	-.239
Behavior Classification Measures (All Values in Minutes)			
Discriminated Recall - Easy	86.13	126.06	.102
Discriminated Recall - Difficult	25.88	58.08	.049
Classification - Easy	1.02	8.72	-.079
Classification - Difficult	(no instances of this category)		
Rule Using - Easy	86.56	111.85	.368
Rule Using - Difficult	4.18	19.43	.138
Higher Order R.U. - Easy	13.13	37.00	.349
Higher Order R.U. - Difficult	1.57	11.82	-.099
Psychomotor - Easy	14.30	36.23	-.122
Psychomotor - Difficult	(no instances of this category)		
INSTRUCTIONAL DESIGN VARIABLES			
No. of Embedded Questions	16.27	15.18	.590
No. of Self-Check Items	2.74	4.54	-.149
TEST CHARACTERISTIC VARIABLES			
No. of Lesson Mastery Test Items	9.38	6.69	.478
Master Test Criterion (Percent)	57.70	29.75	.288
No. of Performance Test Check Points	8.26	19.04	-.279

TABLE 4

MEANS, STANDARD DEVIATIONS AND FIRST ORDER CORRELATIONS OF PREDICTOR AND CRITERION VARIABLES

(Cont'd)

VARIABLES	MEAN	STD. DEV.	R WITH CRITERION
STUDENT CHARACTERISTIC VARIABLES			
Sex (0 = Female, 1 = Male)	0.87	0.33	-.283
ASVAB Scores			
General	68.85	13.30	-.089
Administrative	59.6[illegible]	18.47	.149
Mechanical	58.97	25.88	-.384
Electrical	65.98	16.65	-.252
Cognitive AIS Preassessment Scores			
Reading Vocabulary	22.37	6.80	-.041
Reading Skills Scale 1	5.38	1.80	-.160
Reading Skills Scale 2	5.[illegible]8	2.18	.218
Concealed Figures	7.96	3.60	-.042
Affective AIS Preassessment Scores			
State Curiosity	65.76	7.77	-.049
State Anxiety	38.89	8.36	.084
Test Anxiety	30.11	7.[illegible]	.182
Internal-External	14.43	[illegible].88	-.021
Audio Preference	11.09	3.04	-.007
Visual Preference	7.89	2.22	-.147
Printed Preference	4.39	1.44	.069
Conventional Instruction Experience	6.94	1.64	-.012
Self-Paced Instruction Experience	5.45	1.35	-.095
CRITERION VARIABLE			
First-Attempt-Lesson Time	84.90	64.74	-

the full model, and the model with the smaller number of predictors is called the restricted model. The reduction in R^2 is F distributed with degrees of freedom df_1/df_2 according to the following equation.

$$F = \frac{(R_f^2 - R_r^2) / (df)_1}{(1 - R_f^2) / (df)_2}$$

where $R_f^2 = R^2$ of the full model,

$R_r^2 = R^2$ of the restricted model,

$(df)_1 = n_f - n_r$, the difference between the number of linearly independent predictor vectors of the full (n_f) and restricted (n_r) models, and

$(df)_2 = N - n_f$ where N is the total number of cases.

For the linear model comparisons in this study, SPSS regression program options were used to delete predictor variables and to generate composite predictors. The R^2 values were obtained from the SPSS program, and the F values were obtained from a FORTRAN program produced by the AIS project staff. Stepwise multiple regression analysis is simply multiple regression analysis performed by adding, step by step, the predictor variable which yields the highest F value for the increase in R^2 according to the above equation. The SPSS multiple regression programs include a stepwise option which was employed where appropriate for this study.

The models employed in this series of linear model comparisons did not control for the effect of repeated measures on the lesson variables. There are several reasons why this was not done. First, one controls for the effect of a particular variable, e.g., subjects, to increase the precision of an F-test between two models. The very large n in this study provided sufficient precision so that additional control over extraneous error variance was not necessary. In general, the F-tests resulting from model comparisons were highly significant. Second, the effects of the repeated measures were curtailed by the fact that the repeated observations for a given subject were for different lessons (different learning tasks) rather than on the same lesson and that subjects with repeated measures varied with regard to the sets of lessons on which the measures were repeated. Third, to control for the repeated measures would have required the generation of a binary vector to represent each individual student. This would have far exceeded the capacity of the SPSS program. Finally, it must be remembered that the purpose of the resultant regression model was to predict first-attempt-lesson-time given only the characteristics of the lesson and of a generally defined student population. Thus, the user of the prediction equation would have no means by which to identify individual students.

Cross validation of the final regression equation model also employed the SPSS regression program. SPSS regression program options were used to define a variable, predicted first-attempt-lesson-time, which was the result of the application of the final regression equation to data from Sample Two. The values of this variable were than correlated with actual Sample Two, first-attempt-lesson-times.

4.3.2 Elimination of Two Variables Highly Correlated with the Criterion - Early analyses indicated the presence of two variables which were highly correlated with the criterion of first-attempt-lesson-time. These were the instructional design variables, Number of Embedded Questions ($r = .590$), and the test characteristic variable, Number of Lesson Test Items ($r = .478$). Since these variables were also highly correlated with a number of other variables, they tended to mask the relevance of these potential predictors and accounted for more of the variability than was logically justified.

It will be recalled that the numbers of Embedded Questions and Lesson Test Items were taken directly from existing AIS materials. This action was justified on the assumption that the numbers of items reflected instructional design decisions which could be made prior to the development of self-paced materials. Unfortunately for this study, AIS material developers employed a consistent policy with regard to the number of embedded and lesson test questions throughout their instructional development effort in both of the courses sampled. Thus, almost all of the variability in these two variables could be traced directly to the amount of subject matter content in each lesson and, hence, its average first-attempt-time. Since the current study was basically a survey, and direct manipulation of the various predictor variables was not feasible, some problems of this type had to be expected. Despite the resultant loss of predictability, it was imperative that these two variables be deleted from the predictor set in order to obtain a realistic assessment of the relevance of the remaining variables.

Two linear model comparisons were made in eliminating these two variables. The full regression model, prior to elimination of the variables, contained 34 predictors - all of those, other than the behavior classification measures, are shown in Table 4. The multiple correlation coefficient obtained was .68599, R^2 = .47058. Elimination of the Embedded Questions variable reduced proportion of the variance accounted for to R^2 = .42525. A test for the significance of the reduction in R^2 resulted in an F (1, 2939) = 251.643, p < .001. When the variable Number of Lesson Test Items was removed, R^2 was further reduced to .40413, F (1, 2940) = 108.034, p < .001.

4.3.3 Reduction of Predictor Set Through Linear Models Comparisions - A series of linear model comparisons was made in order systematically to obtain a more parsimonious set of predictor variables. Although the specific questions of interest could have been asked by isolating the relevant variables, it was considered more appropriate that the comparisons be made in the context of the complete set of remaining predictors. In all of the comparisons to be discussed, emphasis was placed on cost-effectiveness rather than on statistical significance. Due to the magnitude of the data base, almost all of the linear model comparisons resulted in significant differences. In general, however, the increased cost of obtaining data required by the additional variables in the full model did not appear to be justified by the increment in predictability provi : by the full model. Therefore, the decision rule adopted was to select the restricted model unless the reduction in R^2 approached or exceeded .01000.

4.3.3.1 Course Content and Behavior Classification Measures - An obvious first step in reducing the variable set was to select one of the two approaches for classifying course content. Prior to comparing the two approaches, however, the extent to which the number of variables in each set could be reduced was investigated. The content classification scheme was attacked first.

The initial full model, Model 1, contained the 32 variables remaining after Number of Embedded Questions and Number of Lesson Test Items had been deleted and excluding the behavior classification Variables. The multiple correlation generated by Model 1 was .63572, R^2 = .40413.

The first question asked concerned whether the simplicity/complexity dimension employed by this approach added substantially to the scheme's predictive utility. A restricted model, Model 2, was defined from Model 1 by deleting the following three rating scale variables: Memory - Simple/Complex; Cognitive - Simple/Complex; and Psychomotor - Simple/Complex. Model 2 resulted in an R^2 of .38395, a reduction from Model 1 of .02018, F (3, 2941) = 33.200, $p < .001$. This was considered to be too great a loss in predictability for the cost of obtaining the simple/complex ratings, and the decision was made to retain the rating scales, i.e., Model 1.

Attention was then directed to the behavior classification approach. A full model, Model 3, was defined which consisted of 34 predictor variables. Model 3 differed from Model 1 in that the eight behavior classification measures were substituted for the six content classification measures. As was noted in Table 4, the lessons sampled provided data for only eight of the ten behavior classification measures. No instances of Difficult Classification or Difficult Psychomotor tasks were encountered.

Model 3 resulted in an R^2 of .36057 as compared with an R^2 of .40413 for Model 1. Thus, it was immediately obvious that the content classification approach was preferable in terms of level of predictability. The proposed questions of interest regarding the behavior classification approach were conducted anyway.

The first question asked was similar to that asked regarding the content classification scheme - could the easy/difficult dimension be dropped without substantive loss in predictability? A restricted model, Model 4, was defined in which the eight available behavior classification predictor variables were reduced to five. The values of Discriminated Recall-Easy and -Difficult, were added together to produce a simple Discriminated Recall variable. The same procedure was repeated with respect to Rule Using-Easy and -Difficult and Higher Order Rule Using-Easy and -Difficult. Model 4 resulted in an R^2 of .35451, a reduction from Model 3 of .00606, F (3, 2939) = 9.285, $p < .001$. Since the reduction in R^2 was substantially less than 0.01, deletion of this dimension would appear justified in view of the difficulty of obtaining the easy/difficult ratings and their probable unreliability.

A second question was concerned with the utility of the behavior category Higher Order Rule Using. Relatively few of the lesson samples contained examples of this type of behavior. It was thought that this might well be a typical circumstance in military technical training where even most troubleshooting tasks have largely been reduced to a procedure-following activity. Therefore, a further restricted model, Model 5, was defined in which the values of the variables Higher Order Rule Using and Rule Using were added together to produce a single Rule Using variable. Model 5 resulted in an R^2 of .35443, a reduction from Model 4 of only .00008, F (1, 2942) = 0.365, p = .546. This was obviously not a sufficiently substantive loss in predictability to justify generation of the two separate categories Rule Using and Higher Order Rule Using.

As was mentioned above, the full behavior classification model (Model 3) resulted in a smaller R^2 than did the final content classification model (Model 1). This was despite the fact that Model 1 contained fewer predictor variables (32) than did Model 3 (34). An F test was therefore inappropriate as well as unnecessary, and Model 1 was selected. That is, the six content classification variables were retained as predictors, and the behavior classification variables were deleted from the predictor set.

Of the two approaches, the content classification scheme was also considered more desirable on practical grounds. It will be recalled that the content ratings were generated by course materials development and instructional personnel, the type of personnel who would be most readily available to rate the content of a course being considered for self-pacing. The more esoteric behavior classification scheme was conducted by instructional psychologists familiar with the behavioral concepts and terminology. It can be assumed that more extensive rater training would be required if course personnel were required to produce the behavior ratings.

4.3.3.2 Quantitative Course Content Measures - It will be recalled that the time allocated to the conventional lesson by the POI was broken down into five categories: Lecture/Discussion; Demonstration/Performance-Cognitive; Demonstration/Performance-Psychomotor; Programmed Instruction/AV; and Outside Assignment. The question of interest concerned the necessity of these five categories. The most likely candidate for reduction appeared to be the Cognitive and Psychomotor subsets of Demonstration/Performance time. The model resulting from the course content comparisons, Model 1, was employed as the full model. The restricted model, Model 6, differed from Model 1 in that it included only a single Demonstration/Performance variable, and was generated by summing the values of the Demonstration/Performance-Cognitive and -Psychomotor variables in Model 1. Model 6 resulted in R^2 of.38800, a reduction from Model 1 of .01613, F (1, 294) = 79.612, $p < .001$. The cost of generating these two sub-categories was considered justified by the increased predictability. Model 1 was again retained.

The overall utility of breaking total conventional lesson time down into five components was of some interest. To investigate this question, Model 1 was again employed as the full model, and a restricted model, Model 7, was defined which contained a single quantitative measure of course content - the total number of minutes allocated to the lesson by the POI. This variable was generated by summing the values of the five component times. Model 7 resulted in an R^2 of .29748, a reduction from Model 1 of .10665, F (1, 2941) = 131.597, $p < .001$. There would appear to be no question but that the use of the individual component times is well justified.

4.3.3.3 Student Characteristic Measures - The final set of comparisons connected the utility of the various AIS pre-assessment measures. While it can be assumed that ASVAB scores will generally be available, the cost of obtaining data comparable to the pre-assessment measures could only be justified if they made a substantial contribution to the predictive model's utility. Of the two categories of pre-assessment measures, the affective measures were considered the most promising. It was reasoned that the cognitive measures would probably not add much to a predictor set which already contained ASVAB scores. A restricted model, Model 8, was defined from which the four cognitive pre-assessment measures were deleted. Model 1 was employed as the full model. The restricted model resulted in an R^2 of .40230, a reduction from Model 1 of only .00183. This difference was not significant (F (4, 2941) = 2.258, $p = .061$). The restricted model, Model 8, was therefore selected.

Finally, the effect of deleting the affective variables was evaluated. Model 8 was employed as the full model, and a restricted model, Model 9, was defined which contained no pre-assessment variables. Model 9 generated an R^2 of .39570, a reduction from Model 8 of .00652, F (9, 2945) = 3.570, $p < .001$. Although the difference was significant, the increased predictability contributed by the affective pre-assessment measures was not considered to justify their cost for this application. Therefore, Model 9 was retained as the final predictor set.

The limited utility of the preassessment variables for this study should not be generalized to their function as predictors in an individualized instructional system. The preassessment variables selected were those common to both the IM and WM courses; however, the course content levels sampled by this study were much more heterogeneous than would generally be expected in a single, technical training course. Course-specific, individual difference measures of the type represented in the AIS preassessment battery could well provide the finer differentiation required when dealing with students in a single course. More importantly, it must be remembered that the initial CMI mode of AIS operation from which this Study's data were drawn did not include individualized assignment of instructional alternatives. If a proposed self-paced course were to include alternative instructional treatments assigned on an individual basis, measures such as those in the preassessment battery could well make a substantive contribution in a predictive model.

4.3.4 Resultant Regression Model to Predict First-Attempt-Lesson-Time - The 19 variables contained in Model 9 were submitted to the SPSS stepwise Multiple Linear Regression Analysis program. On the basis of this analysis, 14 of the 19 variables were selected for the final regression equation. The cutoff was made at the point at which no one of the remaining variables significantly ($p < .01$) increased the overall multiple correlation. The final 14 variables, their coefficients to five significant digits, and the multiple R and R^2 at each step are shown in Table 5 in their order of entry into the regression equation.

The final regression equation produced a multiple R of .62832, thus accounting for 39.48 percent of the variance in first-attempt-lesson-time for Sample 1. All of the five quantitative course content measures entered the equation. As would be expected, the time required to teach the lesson in the conventional course was

TABLE 5

MULTIPLE LINEAR REGRESSION EQUATION
PREDICTING
FIRST ATTEMPT LESSON TIME

VARIABLE	COEFFICIENT	BETA WEIGHT	MULTIPLE R	R^2
Constant	58.136			
Lecture/Discussion Minutes	0.11689	0.17618	.4886	.2388
Demonstration/Performance Minutes-Cognitive	0.25768	0.25651	.5608	.3145
ASVAB Mechanical Score	-0.26054	-0.10415	.5764	.3322
Memory Content Minutes	-0.17944	-0.19951	.5883	.3461
Simple/Complex Memory Rating	14.928	0.17171	.6005	.3606
No. of Self Check Items	-0.98747	-0.069196	.6047	.3657
Psychomotor Content Minutes	-0.20393	-0.16736	.6098	.3719
Programmed Instruction/AV Minutes	0.27739	0.16567	.6203	.3848
Sex	-16.202	-0.083742	.6238	.3891
Demonstration/Performance Minutes-Psychomotor	-0.088128	-0.086009	.6255	.3913
ASVAB Administrative Score	-0.10187	-0.029058	.6261	.3919
Simple/Complex Psychomotor Rating	1.9439	0.056918	.6[illegible]	.3927
Cognitive Content Minutes	0.15746	0.35841	.6[illegible]	.3934
Outside Assignment Minutes	-0.14308	-0.28089	.6283	.3948

strongly related to the self-paced lesson completion time. Five of the six content classification measures were included. It is interesting to note that the measures Memory Content Minutes and Psychomotor Content Minutes were inversely correlated with the criterion, i.e., the greater the amount of this type of content, the shorter the first-attempt-lesson-time. This implies that substantial time reductions can be realized through self-pacing in these areas. The one remaining instructional design variable, Number of Self-Check Items, also entered with a negative coefficient. This would imply that the time required for such post-instructional organizers is more than justified. Neither of the two remaining test characteristic variables, Lesson Test Criterion or Number of Performance Test Check Points was found to contribute significantly to the multiple regression equation. With regard to student characteristic variables, sex was found to be relevant, entering with a negative coefficient implying that, for the material sampled, males tend to progress more quickly than do females. Finally, the ASVAB Mechanical and Administrative scores entered with, as would be expected, negative coefficients. Given the presence of those two scores, ASVAB General was not found to contribute significantly to the equation.

4.3.5 Test of the Model's Validity and Generality - The generality of the regression equation model was evaluated by two means, cross validation and a test of course independence. The same constraints which had been applied to Sample One were applied to the 6849 cases in Sample Two, which, along with the casewise deletion of mission data, reduced the sample size to 2830 cases. The Sample Two means and standard deviations of the 14 predictor variables and the criterion variable are shown in Table 6. The comparable Sample One values are also shown for the sake of comparison.

For the cross validation, the final regression equation, shown in Table 5, was applied to the Sample Two data. The resultant distribution of predicted first-attempt-lesson-times had a mean of 83.91 and a standard deviation of 39.23. The correlation between the predicted and actual first-attempt-lesson-times was .5843, $R^2 = .3414$ with a standard error of estimate of 50.62 minutes. This correlation was significantly greater than .000 (F (1, 2828) = 1465.840, $p < .001$). Since the original multiple correlation coefficient was .6283, the shrinkage in cross validation amounted to .04400. In terms of R^2, the loss in percentage of the

TABLE 6

MEANS AND STANDARD DEVIATIONS OF RELEVANT VARIABLES FROM SAMPLE USED TO GENERATE REGRESSION EQUATION (SAMPLE ONE) AND SAMPLE USED FOR CROSS VALIDATION (SAMPLE TWO)

VARIABLE	SAMPLE ONE		SAMPLE TWO	
	MEAN	STD. DEV.	MEAN	STD. DEV.
COURSE CONTENT VARIABLES				
Quantitative Measures				
Lecture/Discussion Minutes	89.54	97.58	88.00	95.19
Demonstration/Performance Minutes-Cognitive	55.70	64.45	53.74	63.10
Demonstration/Performance Minutes - Psychomotor	27.91	63.19	27.75	62.42
Programmed Instruction/AV Minutes	8.43	38.67	8.42	38.39
Outside Assignment Minutes	51.27	127.10	49.65	120.21
Content Classification Measures				
Memory Content Minutes	68.86	71.99	68.57	72.33
Simple/Complex Memory Rating	2.61	0.74	2.62	0.75
Cognitive Content Minutes	145.67	147.37	140.26	142.48
Psychomotor Content Minutes	20.95	53.13	20.83	51.18
Simple/Complex Psychomotor Rating	1.23	1.90	1.25	1.93
Instructional Design Variables				
No. of Self-Check Items	2.74	4.54	2.85	4.65
STUDENT CHARACTERISTIC				
Sex (0 = Female, 1 = Male)	0.87	0.33	0.88	0.33
ASVAB Scores				
ASVAB Administrative	59.62	18.47	59.93	18.47
ASVAB Mechanical	58.97	25.88	57.19	22.90
CRITERION VARIABLE				
First Attempt Lesson Time	84.90	64.74	80.10	62.36

variance accounted for amounted to 5.34 percent. The results of the cross validation were considered to be quite satisfactory. It may be concluded that, when applied to data comparable to that used for equation generation, the regression equation model can satisfactorily predict first-attempt-lesson-times.

The question remained, however, as to the extent to which the model would provide satisfactory predictions of first-attempt-lesson-times for a new course, one containing a different type of subject matter. That is, to what extent could the model be generalized to courses other than those employed in the data base? A thorough evaluation of the model's generality would have required the construction of a new data base and was, unfortunately, beyond the scope of the current study. However, a partial test could be made through use of the available data base.

It will be recalled that the data base sampled a total of sixty-four lessons from two courses: twenty-nine from IM, and thirty-five from WM. The question of model generality was rephrased to ask to what extent did unmeasured characteristics of these two courses, i.e., factors specific to each course, contribute to the variability in first-attempt-lesson-time. That is, to what extent could the variance accounted for be increased by knowledge of the course from which the lessons and students were drawn? The degree to which knowledge of course membership increased predictability could be taken as a rough measure of the limitation of the model generality.

A linear models comparison was employed in which the restricted model, Model 10, was defined as containing the 14 variables in the final regression equation. A full model, Model 11, was defined which contained, in addition, a variable representing course number (IM = 1, WM = 4). The full model resulted in an R^2 of .41300. The restricted model, the final regression equation, produced an R^2 value of .3948, a reduction of .01820. This represented a significant reduction ($\underline{F}$ (1, 2958) = 91.71, $\underline{p} < .001$). Thus, specific course membership accounted for an additional 2.0 percent of the variance.

Although significant, the amount of variance accounted for by knowledge of course membership is relatively small. Although some loss in predictability could be expected if the regression equation model were applied to a new course, the results of this final comparison imply that the accuracy of prediction would not be seriously diminished.

4.3.6 Generation of Block-Completion-Times from First-Attempt-Lesson-Times - As was discussed in paragraph 4.2.1, Definition of the Criterion Variable, the criterion variable of interest was block-completion-time. It was, however, necessary to develop the regression equation at the lesson level rather than at the block level in order to obtain sufficient variability in content. Having generated the regression equation, it was now necessary to provide a transition to block level prediction. As was outlined in paragraph 4.2.1, the approach employed was to determine a proportional "lost time" for block completion and the sum of the completion times for all the lessons contained in the block.

As was discussed in paragraph 4.2.3 of this report, none of the nine block samples from the two courses contained a complete set of lessons. This was due to the fact that there were AIS lessons in each block which represented new content, content for which no conventional instruction POIs were available. Since there was no basis for establishing course content predictor variables for these lessons, they were excluded from consideration. Since the data base constructed for this study did not contain any examples of complete blocks, it was necessary to return to the AIS database to obtain the required information, i.e., block-completion-times and first-attempt-times for all of the lessons in each block.

Data were retrieved from each of the nine blocks employed in the current study. A student's data were included in this analysis only if reliable first-attempt-lesson-times were available for all lessons in the block, both those included in the original analyses and those which had previously been excluded. Furthermore, a student's data were excluded if (a) the recorded block-completion-time was less than the sum of the first-attempt-lesson-times or (b) if block-completion-time exceeded reasonable maximums identified by the AIS materials developers. For each student who met these constraints, two values were generated: (a) the sum of first-attempt-lesson times; and (b) block-completion-time. The difference between these two values was then expressed as a proportion of the sum of first-attempt-lesson-times. This constituted the "lost time" ratio for that student. A mean lost time was then calculated for each of these nine blocks. A final mean was determined on the basis of these nine values. The reason for computing the mean in two steps rather than simply summing across blocks was to avoid biases introduced by unequal numbers of observations in the various blocks.

The resultant lost time ratio was 0.40. That is, on the average, block completion time was found to equal 1.40 x (sum of first-attempt-lesson-times). As may be seen by reference to the Descriptive Model (Figure 2), this unmeasured lost time was comprised of the time attributable to the following activities: (a) queuing for lesson resources and test scoring (relatively negligible times); (b) remedial study, queuing and retesting on failed lessons; (c) administrative overhead; (d) credentialling testing and queuing for test scoring; and (e) block level remediation following failure of a credentialling test. In the Cost Model, to be discussed in Section 5.0 of this report, the product of the regression equation was multiplied by 1.40 to obtain an estimate of block-completion-time.

5.0 THE COST MODEL

One of the objectives of this study was the modification of a cost analysis computer program previously developed by the Rand Corporation. Specifically, the Rand model was reprogrammed to use the regression equation developed in this study as the method for generating predictions of course completion times for students. The unmodified Rand model uses a completion time entered by the user without specifying how this time was estimated.

The Rand MODIA cost model (Hess and Kanter, 1976) is actually comprised of three computer programs: a user interface program (UI); a resource utilization model (RUM); and a cost analysis program (MODCOM). The UI is an interactive program which produces a course description in computer-compatible data which can be input into the RUM. The RUM is a batch program which produces detailed course operation reports regarding student flow patterns and waiting times as well as resource demand and utilization. The UI and RUM are designed to be used repeatedly until the course planner has generated several course designs. The costs of these alternative course descriptions are then compared by the batch process cost model program (MODCOM). Resource requirements from the UI, RUM, user supplied course completion times, and cost and manning data are input into MODCOM to produce total course costs for up to five years. On some of the cost and manning factors, default values are used if not supplied by the analyst.

The computer program developed in this study is named Aid for Instructional Development and Evaluation (AIDE). It is a modification of the MODCOM cost analysis program and retains all of the cost analysis features and outputs of MODCOM while allowing for course completion time to be estimated by the regression equation developed in this study.

Although AIDE inputs are sufficiently documented in this report for it to be used by itself, it is designed to be used as a replacement for MODCOM in the MODIA series of programs, and the detailed MODCOM documentation should be used with AIDE.

5.1 DESCRIPTION AND USE OF THE AIDE PROGRAM

The AIDE program projects the investment and operating costs of a given course design for a five-year time frame. Course completion time for each type of student is computed and used to calculate student pay and allowances costs. The number of student entrants per year and their completion times are used to determine resource requirements and costs. Resources include manpower, courseware, hardware, and facilities. These resources require specification in terms of quantities such as attrition rates, and utilization rates. These specifications are outputs of the MODIA UI and RUM programs or may be supplied from knowledge of a specific course. Flexibility in the inputs required allows the model to be used at any level of detail desired.

The following outputs are generated by the AIDE program:

- o Input Data Listing
- o Input Lesson Descriptor Values Listing
- o Course Completion Data Generated by the Regression Model
- o Personnel Distributions and Cost Factors
- o Graduate Summary
- o Manpower Summary
- o Courseware, Hardware, and Facilities Requirements by Year
- o Functional Cost Summary.

These outputs are illustrated in Figures A-1 through A-8 in Appendix A. AIDE outputs 4 through 8 are identical with the original MODCOM outputs. Output 1 differs only in that the additional student and lesson variables unique to AIDE are listed. Outputs 2 and 3 are unique to AIDE. Output 2 provides a complete list of the input lesson descriptor variables, and Output 3 is a summary of the course completion data generated by the regression equation.

A description of input data preparation is given in Appendix A. A more detailed description of the data input is provided by the RAND MODCOM documentation. Any differences in input data preparation between AIDE and MODCOM are noted specifically in Appendix A. In general, the differences between the two programs are that the AIDE regression equation requires input of values for three student descriptor variables for each type of student defined and values for the eleven course descriptor variables. The particular regression equation developed in this study is currently hardcoded in the AIDE program, but AIDE could be changed to employ any similar regression equation with only minor changes to the FORTRAN code (as noted in Appendix A).

One limitation of the AIDE cost analysis program is that, while there is variability in the predicted course completion times generated by the regression equation, no corresponding variability is computed for course costs by the cost model.

Although AIDE can take up to 75 different lessons as defined by their lesson descriptor variables, it should be noted that the original (conventional course) lesson lengths in this study were approximately one to seven hours. Thus, the prediction equation for individualized lesson and completion times should not be generalized to lessons whose original lengths fall outside this range. Regarding input data preparation, original course lengths outside of this range should be broken down into sums of lessons whose lengths fall within the above range.

5.2 EXAMPLE USE OF AIDE

To illustrate how the AIDE program can be exercised, course completion and cost data were generated for a standard sample and for additional samples representing three specific questions discussed in paragraphs 5.2.1 through 5.2.3.

Input data for all of these samples were obtained primarily from example values given in the MODIA documentation, but a number of values were representative of available AIS data. Specifically, these values were (a) a conventional course length of 50 hours, (b) a student washout rate of 10 percent, (c) a student entry interval of once per 30 hours, (d) a total student entry rate of 3200 per year or approximately 60 per week, (e) lesson descriptor variables, and (f) student characteristic variables. For the standard sample, an approximate normal distribution of student variable values was chosen for the ASVAB Administrative (ASVADM) and Mechanical (ASVAMEC) scores. The mean values of these two distributions were set equal to the mean values of Sample One from the regression analysis section of this study. Sex was held constant by defining an all male sample. Likewise, student personnel type, designation, and paygrade value were held constant for all students at values derived from the MODIA documentation.

Figures A-1 through A-8 in Appendix A illustrate the AIDE output for this standard sample. Figure A-2 lists the values of the lesson variables, and Figure A-3 lists the values of the student variables. The standard sample time and cost results are summarized in Table 7. The first portion of the table, Course Completion Data, is derived from the AIDE program Output 3 (Figure A-3 in Appendix A). It lists the expected course completion times for students of five differing ability levels as measured by the ASVAB Administrative (ASVADM) and Mechanical (ASVMEC) scales. The average expected course completion time across all students is shown to be 19.17 hours, a savings of 52.1 percent from the conventional course length of 40 hours. The second portion of the table, the Functional Five Year Cost Summary, is derived from AIDE Output 8 (Figure A-8 in Appendix A). The figures shown for each category are totals over the initial five year period assuming the distribution of student ability levels shown in the top portion of the table. The various cost items are described on pages A-27 and -28 of Appendix A.

TABLE 7

AIDE TEST RUN FOR STANDARD SAMPLE

COURSE COMPLETION DATA (IN HOURS)

Student Variables ASVADM	ASVMEC	Course Completion Time (Hrs.)
84	85	17.0
72	72	18.1
60	59	19.2
48	46	20.2
36	33	21.3

Average Course Completion Time is 19.17 Hours

Average time Savings is 52.1 Percent

FUNCTIONAL FIVE YEAR COST SUMMARY

Courseware Procurement	
Printed Media	$136,700
Display Media	48,000
Software	13,100
Hardware Procurement	
Media Hardware	22,400
Special Equipment	0
Overhead Hardware	2,000
Facility Construction	75,000
Pay and Allowances	
Students	1091,700
Instructors	1644,800
Curriculum Personnel	79,300
Facilities Maintenance Personnel	204,500
Training Admin. Personnel	60,000
Base Operating Support Personnel	335,000
Medical Personnel	59,100
PCS Costs	
Students	7166,700
Instructors	25,400
Instructor Training	
Factory Training of Initial Cadre	3,000
Education Training	54,200
Miscellaneous Operating Costs	
Computer Service Charges	330,000
Hardware Replenishment/Repair	8,000
Miscellaneous Supplies	43,400
TOTAL COURSE COST	$11,675,600

It should be understood that the purpose here was to illustrate how the cost model can be exercised, not to provide an accurate description of the cost structure of an AIS course. If the data were to be representative of an AIS course, it would be necessary to increase the number of lessons in the sample from ten to about 120, and a number of additional inputs would need to be modified to be representative of either the IM or WM course characteristics and students.

5.2.1 Effect of Variation in Student Aptitude Level - The first question investigated asked how cost would be affected if the average level of student aptitude is increased or decreased where aptitude is measured by the ASVAB Administrative and Mechanical scores. The purpose of this particular question was to represent a situation in which an administrator might wish to learn the effects on course costs of lowering course entry requirements (a possible outcome of zero draft) or of raising them (a possible outcome of increased unemployment in the civilian sector).

Two more distributions of student variables were generated which were also approximately normal and whose ASVADM and ASVMEC means were two-thirds of a standard deviation below and one-half of a standard deviation above the mean of the standard sample, respectively. The distributions employed (including the standard sample) are illustrated in Table 8. For each sample, the same number of students was input for each of five years, and all other input variables were held constant. With an entry interval of one week (30 hours), the entry rate was 64 students per week, roughly the number of weekly student entries in the AIS IM course at Lowry AFB.

TABLE 8

DISTRIBUTIONS OF STUDENT VARIABLES FOR COMPARISON OF STANDARD, BELOW AVERAGE, AND ABOVE AVERAGE STUDENT POPULATIONS

SAMPLE DESCRIPTION	ASVADM	ASVMEC	STUDENT ENTRANTS PER YEAR
	84	85	200
	72	72	800
Standard Sample	60	59	1200
	48	46	800
	36	33	200
	96	98	200
	84	85	800
Above Average Sample	72	72	1200
	60	59	800
	48	46	200
	72	72	200
	60	59	800
Below Average Sample	48	46	1200
	36	33	800
	24	20	200

The time and cost results for the two Above and Below Average student samples are given in Tables 9-1 and 9-2, respectively. These Tables are in the same format as Table 7, and the data were derived from the same AIDE program outputs, i.e., Output 3 and Output 8.

For purposes of comparison, data from Tables 7, 9-1 and 9-2 are summarized

TABLE 9-1

AIDE TEST RUN FOR ABOVE AVERAGE STUDENT SAMPLE

COURSE COMPLETION DATA (IN HOURS)

STUDENT VARIABLES		COURSE COMPLETION TIME (HRS.)
ASVADM	ASVMEC	
96	85	16.7
84	72	17.8
72	59	18.9
60	46	20.0
48	33	21.0

Average Course Completion Time is 18.88 Hours

Average Time Savings is 52.8 Percent

FUNCTIONAL FIVE YEAR COST SUMMARY

Courseware Procurement	
Printed Media	$ 136,700
Display Media	48,000
Software	13,100
Hardware Procurement	
Media Hardware	20,900
Special Equipment	0
Overhead Hardware	1,800
Facility Construction	75,000
Pay and Allowances	
Students	1075,700
Instructors	1644,800
Curriculum Personnel	79,300
Hardware Maintenance Personnel	195,000
Facilities Maintenance Personnel	60,000
Training Admin. Personnel	335,000
Base Operating Support Personnel	273,300
Medical Personnel	59,100
PCS Costs	
Students	7166,700
Instructors	25,400
Instructor Training	
Factory Training of Initial Cadre	3,000
Education Training	54,200
Miscellaneous Operating Costs	
Computer Service Charges	330,000
Hardware Replenishment/Repair	7,500
Miscellaneous Supplies	42,900
TOTAL COURSE COST	$11,647,400

TABLE 9-2

AIDE TEST RUN FOR BELOW AVERAGE STUDENT SAMPLE

COURSE COMPLETION DATA (IN HOURS)

STUDENT VARIABLES		COURSE COMPLETION TIME (HRS.)
ASVADM	ASVMEC	
72	85	17.3
60	72	18.4
48	59	19.5
36	46	20.5
24	33	21.6

Average Course Completion Time is 19.45 Hours

Average Time Saving is 51.4 Percent

FUNCTIONAL FIVE YEAR COST SUMMARY

Courseware Procurement	
Printed Media	$ 136,700
Display Media	48,000
Software	13,100
Hardware Procurement	
Media Hardware	22,400
Special Equipment	0
Overhead Hardware	2,000
Facility Construction	75,000
Pay and Allowances	
Students	1108,100
Instructors	1644,800
Curriculum Personnel	79,300
Hardware Maintenance Personnel	204,500
Facilities Maintenance Personnel	60,000
Training Admin. Personnel	335,000
Base Operating Support Personnel	278,300
Medical Personnel	59,100
PCS Costs	
Students	7166,700
Instructors	25,400
Instructor Training	
Factory Training of Initial Cadre	3,000
Education Training	54,200
Miscellaneous Operating Costs	
Computer Service Charges	330,000
Hardware Replenishment/Repair	8,000
Miscellaneous Supplies	43,900
TOTAL COURSE COST	$11,697,500

in Table 10. As may be seen from Table 10, dramatic variations in aptitude in the student population, as measured by the ASVAB Administrative and Mechanical scores, have relatively little effect on course completion time, approximately 1.5 percent. This is due to the fact that, in the regression equation employed (see Table 5), these two variables, although significant, account for relatively little of the variability in first-attempt-lesson-time. The effect on Total Course Cost is even less, approximately 0.2 percent. This is due to the relatively large fraction of the course costs which are considered by the model to be fixed rather than dependent on variable course length.

TABLE 10

TIME AND COST COMPARISONS FOR DIFFERENT STUDENT DISTRIBUTIONS

SAMPLE DESCRIPTION	AVERAGE TIME		STUDENT PAY COST		TOTAL COURSE COST	
	Hours	% Change	$*	% Change	$*	% Change
Above Average	18.88	-1.5	1075.7	-1.5	11647.4	-0.24
Standard	19.17	0.0	1091.7	0.0	11675.6	0.00
Below Average	19.45	1.4	1108.1	1.5	11697.5	0.19

* In Thousands of Dollars

5.2.2 <u>Effect of Variation of Proportion of Memory Versus Cognitive Content</u> - The second question investigated the effect of variations in the relative proportions of Memory to Cognitive content. The purpose of this question was to illustrate the differing outcomes that may be expected when courses with different characteristics are individualized. The variables in the regression equation (Table 5) indicated that individualization of a course containing a relatively large amount of memory content would result in more substantive time savings than would individualization of an otherwise similar course with less memory and more cognitive content.

To investigate this question, the number of minutes of memory content material (MEM) in the course represented in the standard sample was increased by one standard deviation, i.e., 72 minutes per lesson. In order to keep lesson lengths constant, a corresponding reduction of 72 minutes per lesson was made in the amount of cognitive content (COG). This represented a reduction of 0.49 standard deviations in the cognitive content.

The Time and Cost results for this high-memory-content course are given in Table 11 which employs the same format as Table 7. For purposes of comparison with the standard sample, data from Tables 7 and 11 are summarized in Table 12. As may be seen from Table 12, substantially greater time savings would be expected from individualization of a course with a higher percentage of memory content. While the predicted average course completion time for the standard sample course was 19.17 hours (down from 40 hours as taught by conventional methods), the predicted average course completion time for the high-memory-content course (also assuming a 40 hour conventional course baseline) was only 13.51 hours.

Again, it should be noted that while there are large differences in student pay costs between the two types of courses (29.5 percent), the difference in Total Course Cost is relatively small (8.1 percent).

TABLE 11

AIDE TEST RUN FOR HIGH-MEMORY/LOW-COGNITIVE-CONTENT COURSE

COURSE COMPLETION DATA (IN HOURS)

STUDENT VARIABLES		COURSE COMPLETION TIME (HRS.)
ASVADM	ASVMEC	
84	85	11.4
72	72	12.4
60	59	13.5
48	46	14.6
36	33	15.7

Average Course Completion Time Is 13.51 Hours

Average Time Saving Is 66.2 Percent

FUNCTIONAL FIVE YEAR COST SUMMARY

Courseware Procurement	
Printed Media	$ 136,600
Display Media	48,000
Software	13,100
Hardware Procurement	
Media Hardware	13,400
Special Equipment	0
Overhead Hardware	- 300
Facility Construction	75,000
Pay and Allowances	
Students	769,300
Instructors	1252,800
Curriculum Personnel	79,300
Hardware Maintenance Personnel	142,500
Facilities Maintenance Personnel	60,000
Training Admin. Personnel	289,500
Base Operating Support Personnel	205,300
Medical Personnel	43,100
PCS Costs	
Students	7166,700
Instructors	19,200
Instructor Training	
Factory Training of Initial Cadre	3,000
Education Training	40,700
Miscellaneous Operating Costs	
Computer Service Charge	330,000
Hardware Replenishment/Repair	5,500
Miscellaneous Supplies	32,400
TOTAL COURSE COST	$10,725,100

TABLE 12

TIME AND COST COMPARISONS FOR STANDARD AND HIGH MEMORY/LOW COGNITIVE CONTENT COURSES

SAMPLE DESCRIPTION	AVERAGE TIME		STUDENT PAY COST		TOTAL COURSE COST	
	Hours	% Change	$*	% Change	$*	% Change
Standard Sample with Mean Values on MEM, COG	19.17	0.0	1091.7	0.0	11675.6	0.0
Standard Sample with MEM increased 1 S.D., COG decreased 0.49 S.D.	13.51	-29.5	769.3	-29.5	10725.1	-8.1

* In Thousands of Dollars

5.2.3 Effect of Variation of Conventional Course Presentation Methods - One of the most striking aspects of the regression equation to predict first-attempt-lesson-time (Table 5) was the difference between the coefficients of two of the quantitative course content variables: Lecture/Discussion Minutes and Demonstration/Performance Minutes - Cognitive. According to these coefficients, each additional minute of Lecture/Discussion presentation in the conventional course would be expected to increase first attempt lesson time in the individualized course by only 0.12 minutes. In contrast, each additional minute of Demonstration/Performance-Cognitive presentation would be expected to increase first-attempt-lesson-time in the individualized course by 0.26 minutes. On the assumption that these values were approximately correct, a final comparison was made to illustrate the differing effects of individualizing two courses which differed on these dimensions.

For the purpose of this comparison, the number of minutes of Cognitive Demonstration Performance time (CDPMC) was increased by 0.75 standard deviations (48 minutes) per lesson. A corresponding reduction of 48 minutes per lesson in Lecture/Demonstration time (CLDM) amounted to a change of 0.49 standard deviations.

The time and cost results for this high-demonstration/performance-method course are given in Table 13 which employs the same format as Table 7. For purposes of comparison with the standard sample, data from Tables 7 and 13 are summarized in Table 14. As may be seen from Table 14, no time savings would be expected from the individualization of a course which employed Demonstration/Performance methods for this very high proportion of the content. The predicted average course completion time for the individualized high-demonstration/performance-method course was 44.52 hours, an increase of 4.52 hours over the conventional course.

TABLE 13

AIDE TEST RUN FOR HIGH-DEMONSTRATION/PERFORMANCE-METHOD COURSE

COURSE COMPLETION DATA (IN HOURS)

STUDENT VARIABLES ASVADM	ASVMEC	COURSE COMPLETION TIME (HRS.)
84	85	42.0
72	72	43.4
60	59	44.5
48	46	45.6
36	33	46.7

Average Course Completion Time Is 44.52 Hours

Average Time Saving is -11.3 Percent

FUNCTIONAL FIVE YEAR COST SUMMARY

Courseware Procurement	
Printed Media	$ 137,800
Display Media	48,000
Software	13,100
Hardware Procurement	
Media Hardware	51,400
Special Equipment	0
Overhead Hardware	12,800
Facility Construction	150,000
Pay and Allowances	
Students	2531,600
Instructors	3751,700
Curriculum Personnel	79,300
Hardware Maintenence Personnel	463,600
Facilities Maintenance Personnel	115.500
Training Admin. Personnel	544,300
Base Operating Support Personnel	607,400
Medical Personnel	131,500
PCS Costs	
Students	7154,300
Instructors	67 400
Instructor Training	
Factory Training of Initial Cadre	3,000
Education Training	125,400
Miscellaneous Operating Costs	
Computer Service Charges	410,000
Hardware Replenishment/Repair	17,500
Miscellaneous Supplies	95,600
TOTAL COURSE COST	$16,511,200

TABLE 14

TIME AND COST COMPARISONS FOR STANDARD AND HIGH-DEMONSTRATION/PERFORMANCE-METHOD COURSES

SAMPLE DESCRIPTION	AVERAGE TIME		STUDENT PAY COST		TOTAL COURSE COST	
	Hours	% Change	$*	% Change	$*	% Change
Standard Sample with Mean Values on CDPMC, CLDM	19.17	0.0	1091.7	0.0	11675.6	0.0
Standard Sample with CDPMC increased .75 S.D. CLDM decreased .49 S.D.	44.52	132.2	2531.6	131.9	16511.2	41.4

* In Thousands of Dollars

5.3 DISCUSSION OF AIDE EXAMPLE RUN RESULTS

The three questions discussed above represent simple examples of how the AIDE cost model analysis program may be exercised, using differing student and lesson variable values, to investigate the expected cost savings resulting from individualizing different types of courses. Again, it should be emphasized that the data presented were not intended to be representative of the AIS courses from which the regression equation data base was derived. Neither was the intent to exploit fully the capabilities of the Rand MODCOM program from which the AIDE program was derived.

There are a number of general points which should be explicated. The various example runs indicate that direct student costs, pay and allowances, account for relatively little of the total course costs. For the Standard Sample (Table 7), student pay and allowances account for only 9.35 percent of the total. Although, as is discussed below, some of the cost figures provided are somewhat misleading, these values do illustrate the point that military technical training does have substantial fixed costs which are relatively insensitive to reductions in training time *per se*.

These additional costs were, however, inflated by two pre-analysis decisions reflected in the input data. First, the input data indicated that student relocation for training was to be treated as a permanent change of station (PCS). Given the predicted average course length of 19.17 hours (Standard Sample, Table 7), it would be more cost-effective to handle student relocation through temporary assignment - TDY. PCS costs for the standard sample were $7,166,700 over the five year period; six and one-half times as much as student pay and allowances over the same period. If relocation for training had been handled by means of TDY assignment and if one assumed a six hour training day, this expense would have been reduced to approximately $2,903,500. This figure still represents over two and one-half times the cost of student pay and allowances.

A second factor which increased predicted costs was the decision that the entry interval should be 30 class hours or once per week. Given that the average course completion time was predicted to be less than 20 hours, very few students would still be present in the course at the end of the week. While the average student load was computed to be 36.2, the actual number would range from a high of at least 64 students at the time of a class entry to a low of near zero just prior to the next class entry. This represents an extremely inefficient use of both personnel and facilities. Although such a test run was not made, it can be anticipated that a substantive cost reduction would result if the entry interval was reduced to six hours, allowing 12 to 13 new students to enter the course each day.

Although these two factors, permanent change of station and once per week entry, did inflate the estimated costs relative to student pay and allowances, the conclusions drawn concerning the relative costs of the various samples run, i.e., above and below average student ability levels, high-memory/low-cognitive content, etc., remain valid. Even with TDY assignment and daily course entry, student pay and allowances would still contribute only a fairly small proportion to the total course costs.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This study represents the first effort to employ data from an operational environment in an attempt to relate variables such as course content, instructional and system design considerations, and student characteristics to completion time in a self-paced course and to the cost of developing, implementing, and maintaining such a course. The study has, we believe, demonstrated that a viable time savings and cost model can be developed given a sufficient data base from which to draw information. The generality and precision of such a model is, however, dependent on the depth to which the instructional system from which the data are derived can be fully and explicitly described. Analogously, the utility of the model for a given application will depend on the accuracy with which the course being considered for self-pacing is described. In addition to a description of the course content, the model requires a number of assumptions concerning instructional and system design variables and the characteristics of the students to be enrolled in the course. The predictive accuracy of the model will, of course, always be limited by the validity of these assumptions.

As was stated above, the authors believe that the current study has demonstrated the feasibility of developing time savings and cost models which have practical utility. It must be recognized, however, that there is a number of limitations both to the specific model developed here and to future efforts which employ this work as a starting point. Each of the three major components of the overall effort, the descriptive model, the predictive model, and the cost model, will be discussed with respect to these limitations as well as with respect to their positive aspects.

The descriptive model of computer-based training systems can be viewed as serving as a framework for the predictive model and a guide to its development. The utility of the predictive model will always be limited by the generality and completeness of the descriptive model. While the descriptive model employed in this study would appear to be appropriate, it must be recognized that its adequacy was not actually tested by the current effort, since the predictive model developed directly addressed only a small portion of the total descriptive model.

It is suggested, however, that the general characteristics of the descriptive model proposed are appropriate to an effort of this type, i.e., description of an instructional system in terms of a number of time-consuming components and the probabilities associated with a limited number of decision points. Our experience with predicting a single time component (first-attempt-lesson-time) indicates that it is feasible to develop miniature predictive models for the remaining components, given the availability of reasonably accurate data.

The one exception to this generally optimistic view must be noted - prediction of the time component entitled Cumulative Administrative Overhead. The quantity of administrative overhead would appear to be heavily dependent on local course policies. While this assumption needs to be examined in greater detail, it would appear that the time attributable to this component may be too specific to local situations to be estimated with any degree of accuracy on the basis of available data.

A second problem area lies in estimating the probabilities associated with the pass/fail decisions following the various lesson and unit tests. As was discussed in Paragraph 4.2.1 of this report, these decisions again appear to be highly dependent on local course policies. Consequently, predictions based on data from any given course or set of courses will be biased by the policies in effect in those courses and fail to generalize to a new course. The best solution to this problem may be to establish tolerable failure rates as part of the instructional system design specifications and assume that instructional materials and procedures will be developed such that student performance will meet these specifications.

It should be noted that the descriptive model can be viewed as consisting of several nested loops: the time required to complete the major instructional unit; the time required to complete a given lesson; and the time required by the individual components within the lesson completion loop. As a result, the model has the interesting attribute that it is not necessary that all of the individual components be modeled explicitly. To the extent that individual components are modeled accurately, the overall estimate of instructional unit completion time becomes more responsive to variations in content, student characteristics, and instructional method. The model still has utility, however, if only gross estimates are made of the total time required by the set of components which were not modeled. The initial effort represented by this study exemplifies the extreme case of such an approach. The single component, first-attempt-lesson-time, was modeled as accurately as possible under the circumstances. The cumulative time attributable to the remaining components was then estimated as a function of first-attempt-lesson-time. The final result, although not as accurate as might be desired, does provide a useful estimate of the total time required to complete an arbitrary instructional unit. Detailed modeling of any additional component will increase the accuracy of the overall estimate. Thus, further refinement of the model can proceed step-by-step as more data become available.

Discussion of the predictive model brings us to the actual mechanics involved in estimating the time required for an individual student to complete an arbitrary instructional unit. It is of some interest to compare the methodology and results of the current study with the work reported by Wagner, Behringer and Pattie (1973) in predicting individualized course completion. The major differences between the two efforts are a function of their differing objectives. While Wagner, et al, were interested in predicting the time required to complete a particular self-paced course, the intent of the work reported here was to predict the time required to complete an arbitrary instructional unit, given a limited set of characteristics of that unit. Specifically, whereas all of the students in the Wagner, et al, study worked through the same set of materials, the criterion variable in the current study represented the time to complete each of 66 different instructional units. The fact that the multiple correlation coefficient of .6283 obtained here compares favorably with the correlations of .65 to .75 reported by Wagner, et al, indicates that the lesson descriptor variables employed in the current study did accurately represent the characteristics of the various lessons. While Wagner, et al, were able to obtain substantially higher correlations (.85 to .87 through the use of within-course measures, such measures would not have been appropriate to the objectives of the current study. Wagner, et al, also found that the measurement of individual difference characteristics through the use of course content-related instruments was preferable to the use of the standard military battery. The current study found that the use of available preassessment measures did not appreciably increase the accuracy of prediction in the presence of ASVAB scores, but the results might have been different had the preassessment battery contained more content-specific tasks. Again, however, such content-specific measures would have very limited utility given the objectives of the current work.

The regression analysis approach employed in this study would also appear to be appropriate for estimating the time required for many of the remaining components of the Descriptive Model such as Remedial Study Time on Lesson i and the time required for the various diagnostic and credentualling tests. In other cases, such as estimating the time consumed in obtaining resources and test scoring, an alternate approach based on queuing theory might well be more appropriate.

It should be noted that the current study did not fully investigate all aspects of the regression model approach. Only simple, linear predictors were employed. There is reason to believe that accuracy of prediction could have been improved if the effects of nonlinear transformations of the predictor variables had been investigated. For example, it is reasonable to expect that the relationship between first-attempt-lesson-time and student individual differences could be better represented by a curvilinear relationship than by a simple linear relationship. The failure to investigate interactions among the various predictor variables represents an even more serious limitation. The final regression model does not include any terms which are products of two or more predictor variables. As a result, for example, the final regression model contains the assumption that while two students of differing ability levels will complete a given lesson in differing amounts of time, the difference between their two completion times will be independent of the amount of lesson content. That is, if Student A requires ten more minutes than does Student B to complete a particular lesson, the model implies that Student A will also require only ten more minutes than Student B to complete a second lesson containing twice as much content as the first lesson. The incongruity would be resolved if the predictor set contained one or more variables which were the multiplicative products of appropriate student ability and course content measures. The same line of argument implies the desirability of including product terms which incorporate instructional design variables such as the number of self-check items.

The effort required for adequate investigation of potential transformations and product terms was simply not feasible within the temporal and fiscal constraints of the current study. Investigation of at least interaction terms should certainly be given consideration in any work directed at refining the predictive model.

The major limitations of the current study can be traced directly to the lack of a sufficiently broad and reliable data base. To a great extent, any future efforts in this area will be limited by these same constraints. In general, data acquisition problems fall into four broad categories: self-paced student performance data; baseline course content descriptions; the variability of examples of instructional methods; and the distribution of observations across variations in course content, instructional methods, and student individual difference characteristics.

At the time the data collection effort for the current study was being conducted, the AIS was in a relatively rudimentary stage of development, and the only reliable lesson level time data available were first-attempt-lesson-times. Therefore, the predictive model was limited in explicit prediction to this single component. Since that time, further development of the AIS has allowed collection of reliable, remedial study times and lesson completion times. Were the study to be repeated now, a predictive model could be developed which addressed several components of the instructional process. Obviously, future efforts will be more fruitful if they are conducted in the context of an instructional system with a fully developed data collection and recording component.

While there are advantages to conducting future modeling efforts in the context of an established system, there is a definite disadvantage in attempting to model courses which have been conducted under the auspices of such a system for any length of time. The modeling approach employed in this study assumes the existence of course planning documents which pertain to the course as it was taught in a conventional, group-paced mode. Since technical training courses do change, there is, with time, less and less overlap between the current content of the self-paced course and its content when it was taught in the conventional mode. It will be recalled that none of the nine blocks of instruction sampled in this study contained exactly the same content as they did in the earlier, conventional course. If the study were to be repeated now, there would be even less overlap. Proposed changes to the Inventory Management course indicate that within a year almost none of the content in the original, group-paced course will still be taught. It is therefore suggested that any future efforts at model refinement be conducted in the context of an established system to which new courses are being <u>added</u>.

There is undoubtedly a tendency for a given instructional system to shape the instructional methods employed in that system. One tends to find relatively little variability in method across lessons. Thus, the effect of advanced organizers such as the presentation of lesson objectives could not be evaluated in the current study since all of the lessons sampled contained such objectives. Similarly, the numbers of embedded questions and lesson test items were found to be so highly correlated with the amount of lesson content that it was necessary to exclude them from the predictor set. Relatively little of their variability was independent of lesson length. While the post-instructional organizer, Number of Self-Check Items, was retained in the predictor set, the typical number of such items per lesson was so small that one should be hesitant in using the regression equation information to evaluate the utility of such organizers. It would be desirable to sample a much wider variety of values of course content variables in any future efforts at model refinement. The current study's limitation to two courses makes it difficult to disentangle the effects due to differences in course content from those due to unmeasured, course-specific factors. Finally, it would be highly desirable if future work could include examination of a variety of alternative instructional media, including computer-assisted instruction.

The final data problem area concerns the intercorrelation of predictor variables. If it were possible to manipulate directly the variables of interest, one would impose experimental controls to hold other conditions constant while varying one, or at most a limited set, of variables. Since this was not possible, the current study employed a regression analysis approach in an attempt to examine statistically the effects of individual variables. The regression approach is limited, however, in that the confounding effects due to the intercorrelations among variables cannot be controlled. For example, if a particular instructional method was always employed for teaching a particular class of content, and never employed for teaching other categories of content, its effect could never be evaluated. Nor could one determine the expected time savings due to self-pacing with other instructional methods for that class of content. Other, less extreme examples can also present problems. Within the current AIS system, the more expensive audio-visual media are generally employed only for those lessons which experience has proven to be particularly difficult for students when the material was presented in the less expensive, programmed text format. Thus, a regression equation predicting lesson completion time which incorporated a presentation medium variable would, under these circumstances, tend to misrepresent the utility of audio-visual presentation as compared to programmed text because data on the audio-visual mode were not sampled across the full range of lesson content. It is anticipated that problems of this type will continue to be a major limitation to further development of the predictive model.

The computer cost analysis model developed in this study incorporates an estimate of students' course completion time based on relevant course content, instructional design, and student characteristic variables. It thus increases the scope of Rand's MODIA cost model by basing course completion times on predicted values from a regression equation derived from actual data from an operational environment. The flexibility of input preparation allows the model to be used for both general and detailed levels of analysis.

The cost figures produced by the program are only as good as the accuracy of the course description provided and the similarity of the course to be modeled to the AIS courses from which data were sampled in this study. A further limitation of the cost analysis program is that only mean cost values are produced even though considerable variability is associated with the predicted course completion times. Further work on the AIDE cost model could improve its usefulness by computing the variances associated with the final course cost. The inclusion of variances would allow analysis of variance and linear model comparisons to be made on the costs of alternative approaches. As the model now stands, exercising it with respect to questions related to course content, instructional design, and student characteristics produces cost figures which can only be compared in terms of percentage of change without any measure of the significance of the cost differences.

In summary, the current study has provided three products which can facilitate the investigation of cost savings due to the individualization of military training. The Descriptive Model of Computer-Based Training Systems will, hopefully, provide a context within which to investigate the various components of such systems. The Predictive Model has explored a methodology which, with minor variations, can be developed to predict timesavings due to individualization accurately in a variety of training environments. As instructional systems such as the AIS become established, a broad, reliable data base will become available which can be used to support a systematic, empirical approach to the selection of additional courses for individualization. Finally, the AIDE Cost Model has extended the Rand MODCOM program to incorporate the variable course completion times characteristic of computer-based training systems.

One final comment would appear to be appropriate. As was discussed in Section 5.3 of this report, Discussion of AIDE Example Run Results, those training expenses which are directly attributable to students and which are sensitive to variations in course completion time, (i.e., student pay and allowances) form a relatively small proportion of total course costs. If substantive cost savings are to be realized from the individualization of instruction, the total training system, including support personnel and facilities, must be critically examined. For example, the emphasis to date has been on shortening course completion time while holding the number of instructional personnel constant. It may well be more cost effective to allow somewhat longer course completion times while reducing the student/instructor ratio. The coordination of student arrivals and departures from the training base is at least as important as is the efficient use of the student's time in the classroom. Personnel whose duties are only tangentially related to training account for a sizeable portion of a training base's budget. Reducing the length of one or two small enrollment courses by 20 or even 30 percent will not appreciably decrease the number of students on base and will not, consequently, allow any reductions in the number of these support personnel. If, on the other hand, a substantial proportion of the training on a given base were individualized and the expected time savings realized, a number of indirect costs could be reduced. Referring to the functional cost items shown for the standard sample in Table 7, one would expect broad scale reductions in course times to impact the following items: Facility Construction; Instructor Pay and Allowances; Facilities Maintenance Personnel; Training Administration Personnel; Base Operating Support Personnel; Medical Personnel, PCS costs for instructors; and Instructor Education Training. These items account for an additional 21 percent of the total course costs, and reductions in these areas would almost certainly result in substantive savings. It may well be the case that the full potential of computer-based training systems for cost reduction will only be realized when they have become the norm rather than the exception in military training.

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APPENDIX A

AID FOR INSTRUCTIONAL DEVELOPMENT AND EVALUATION

GENERAL

This appendix describes some technical aspects of the AIDE computer cost analysis program. Appendix B gives a complete FORTRAN listing of the AIDE program. Appendix A includes the following:

- o Computer Program Overview
- o Differences Between AIDE and MODCOM Data Inputs
- o Using a different Regression Equation
- o General Comments About the FORTRAN Program
- o Input Data Preparation
- o Computer Program Output Description.

Computer Program Overview

The computer program was called Aid for Instructional Development and Evaluation (AIDE). The development of the AIDE computer program was facilitated by splitting the program into the following major modules:

Input Module: Read and check input data. Input data will include lesson descriptors, student descriptors, instructor data, courseware data, instructional resources data, physical facilities data, and CMI system data. A complete list of the input data is given in a subsequent section of this Appendix.

Course Duration Module: Use the regression model and overhead factor developed in Section 4.0 to compute the average course duration and the percentage timesaving.

Student Flow Module: Use the average time-to-complete the course to compute the average enrollment level in the course.

Resources and Personnel Module: Based on the average enrollment in the course and other user supplied course data, find the courseware development and maintenance manhours, student and instructor staff manhours, instructional hardware and other resources procurement quantities and maintenance manhours, and computer system hardware quantities. In determining these quantities, allowance is made for fluctuations in the enrollment level.

Cost Accumulation Module: Combine personnel and resource quantities with unit costs to arrive at development, initial investment, and annual operations and maintenance costs to operate the course over a period of five years.

Output Module: Write intermediate and final results.

Prior to the start of programming the model, our literature survey and contacts with instructional system developers revealed that the Rand Corporation had been developing an instructional model called MODIA (Methods of Designing Instructional Alternatives). The MODIA Cost Model (MODCOM) was well developed and performed several of the functions needed in the AIDE Model. Specifically, these are:

- Several input routines for courseware, hardware and personnel
- A routine to generate student manyears, given the average time to complete the course

- o Estimation of training administration, base operating support, and medical support personnel
- o A cost accumulation subroutine
- o Routines to summarize input data, intermediate results, and final results.

In view of these similarities, we requested and received a copy of the MODCOM computer program from the Rand Corporation.

The programming efforts were then directed at writing the subroutines to compute the course duration and estimate resource quantities and modifying the MODCOM program so as to integrate it with these subroutines. A listing of the computer program is given in Appendix B. The inputs to be supplied by the user and the outputs of the computer program, are described in the following paragraphs.

Differences Between AIDE and MODCOM Data Inputs

The first 15 data card types of AIDE are similar to those of MODCOM, but AIDE adds a 16th data card type for lesson descriptors. Specific format differences exist in AIDE for the following card types: 3, 9, 10 and 12. AIDE always uses the calculation option where MODCOM gives a choice of calculation or throughput.

Using a Different Regression Equation

A regression equation of up to three student varibables and up to eleven lesson variables can be entered by changing the DATA statement values in lines 91 through 98 of the program AIDE with no other reprogramming necessary. NSVAR and LDES are the number of student and lesson variables respectively. TVAL(11) is the vector of maximum values for the lesson variables. Regression equations of a different combination of variables will require additional changes in the FORTRAN program in PROGRAM AIDE and in subroutines (overlays) READS, READW, AIDEA and AIDEB. Specifically, the common statement of AIDE1A and AIDE2 will be involved as well as read and write formats in PROGRAM AIDE and subroutines READS, READW, AIDEA and AIDEB.

General Comments About the FORTRAN Program

The AIDE FORTRAN Program was developed on the CDC Cyber 73-16 computer at AIS, Lowry Air Force Base, Colorado. The program is presently overlayed to fit within a 130K core memory limit. The overlay will need to be re-setup by a programmer for the local computer facility. The flowcharts and other detailed documentation accompanying the MODCOM FORTRAN program (Hess and Kantar, 1976) apply to AIDE as well, with the exception that AIDE adds three subroutines (READW, AIDEA, and AIDEB) and deletes one subroutine (OUT5).

Input Data Preparation

This section describes the inputs to the AIDE computer program. The general form and style of the inputs are derived from the Rand MODCOM program which played a large part in the development of our AIDE model. The description of the Rand model variables is taken from a report provided to us prior to publication by Rand.

A large amount of data can be entered into the program. Only data relating to lessons (regression model variables), student variable scores, and class entry interval are required. Any other data omitted will be treated either as if it were zero or assigned a default value.

Data are input to the model on cards. Sixteen types of card formats are used, as listed in Table 11. The detailed form of each card is described below. The following general comments apply to all cards:

Format Identifier: All cards must have the format type punched in columns 1 and 2.

Blanks: Unless otherwise specified, all blanks in numeric fields are read as zeros.

Mandatory Inputs: The variables which must be assigned non-zero inputs are: "entry interval (in hours)," on card format 2; student variables scores on card 3; and at least one set of lesson descriptors (card 16). Failure to enter a non-zero value for these variables will result in the printing of an error message and program termination. Format type 99 is used to signify the end of the input data; one card of this type must be present. Failure to enter this card will result in a FORTRAN error message and program termination.

TABLE 11
DATA CARD TYPES

FORMAT NUMBER	CARD TYPES
1	Title Card
2	General Course Factors
3	Student Inputs
4	Instructor Inputs
5	Courseware Inputs
6	Curriculum Manpower Inputs
7	Hardware Procurement Inputs
8	Hardware Maintenance Manpower Inputs
9	Facility Procurement Inputs
10	Facility Maintenance Manpower Inputs
11	Training Administrative, Base Operating Support, and Medical Manpower Inputs
12	Computer Management System Inputs
13	Optional Officer/Airman/Civilian Distribution Overrides
14	Optional Miscellaneous Overrides
15	Optional Pay and Allowance Overrides
16	Lesson Descriptors
99	Termination Card

Card Limit: In order to preserve core memory, it was necessary to put limits on the number of cards of each format type which can be entered for a single run of the AIDE Model. This limit is indicated in the description of each card type. Cards in excess of that limit are deleted from further processing.

Card Deletions: Throughout this section, mention is made of card deletions which will occur if certain input conditions are violated (e.g., input not within acceptable range, and illegal input combinations). All such card deletions will be listed as part of the output with an appropriate error message.

Decimal Points: All input data are entered as real (floating-point) numbers. The implied decimal point location is at the right end of each field unless otherwise specified. However, a punched decimal point always overrides an implied decimal point location.

Format 1: Title Card Card Limit = 1 - This card is used to identify AIDE runs. The title, to be entered in columns 3 through 80, may contain between 1 and 78 alphanumeric characters. If this card is excluded, then the default title, AIDE model, is used.

Format 2: General Course Factors Card Limit = 1 - This card contains inputs. describing washouts, instructor training costs, and the old course duration.

Columns 3-7 (5 column numeric field): Old course duration (in hours). This number, as described in Section 4.2, is the number of hours of instruction presented in the old course. If a value is not entered, the new course duration will be computed, but not time savings.

Columns 8-11 (4 column numeric field): Washout rate (%): The ratio of the number of washouts to the total number of entrants times 100.

Columns 12-15 (4 column numeric field): Entry interval (in hours): The average length of time separating entry classes.

Columns 16-19 (4 column numeric field): Number of months instructors on board in year 0: The number of months the initial instructor cadre will spend preparing for the subject course in year 0. This value, which must be supplied by the planner, should include time required for special factory training and education training as well as time necessary for curriculum development.

Columns 20-24 (5 column numeric field): Cost of initial factory training (in dollars): The total cost, less student pay and allowances, of providing the initial instructor cadre with specialized equipment or system training necessary for course development and conduct. This initial specialized training is usually accomplished at a private contractor's facility. Subsequent specialized training of instructors is usually provided informally by the existing instructor nucleus. This cost should include travel per diem, transportation expenses, destination per diem, and attendance fees (or contract costs), as applicable. The pay and allowances of the initial instructor cadre while in student status will be accounted for elsewhere.

Columns 25-29 (5 column numeric field): Cost of instructor education training ($): The cost of the six-week instructor prerequisite course on education principles.

Format 3: Student Inputs Card Limit = 75 - This card contains inputs relating to the number and type of student entrants, and values of the three student characteristics variables (ASVADM, ASVMEC, SEX).

Breakdown of Student Entrants - The course planner must determine the breakdown of total annual student entrants by personnel type (Active Duty Force Pipeline, Active Duty Force Lateral/Upgrade, Guard/Reserve Pipeline, Guard/Reserve Lateral/Upgrade, Other DoD Pipeline, Other DoD Lateral/Upgrade, Non-DoD), personnel designator (officer, airman, civilian), and paygrade. Typical paygrades for Air Force pipeline and lateral/upgrade students are:

Student Type	Officer	Airman
Pipeline	0 - 1	E - 1
Lateral or Upgrade	0 - 2 thru 0 - 4	E - 3 thru E - 5

Columns 3-4 (2 column numeric field): Personnel Type: Numeric personnel type code as follows:

01 = Active Duty Force Pipeline Student
02 = Active Duty Force Lateral Upgrade
03 = Guard/Reserve Pipeline Student
04 = Guard/Reserve Lateral Upgrade Student
05 = Other DoD (Army, Navy) Pipeline Student
06 = Other DoD (Army, Navy) Lateral Upgrade Student
07 = Non-DoD (MAP) Student

Use of a code outside the range 1 through 7 will result in the deletion of the card.

Columns 5-6 (2 column numeric field): Personnel Designator: Numeric personnel designator code as follows:

1 = Officer
2 = Airman
3 = Civilian-GS (General Schedule)
4 = Civilian-WB (Wage Board)
5 = Non-DoD

Use of a code outside the range 1 through 5 will result in the deletion of that card. Additionally, card deletion will occur if personnel designator 5 is used in combination with any personnel type other than 7.

Columns 7-8 (2 column numeric field): Pay Grade: Standard U.S. Government numeric pay grade codes. The code entered in these columns must be within the range of permissible paygrades for the specified personnel designator or else the card will be deleted. A duplicate personnel type/personnel designator/paygrade combination will also cause a card to be deleted. The number of unique paygrades entered for a given personnel type/personnel designator combination will depend on the required level of accuracy and the ambition of the user: each paygrade requires a separate card entry. ATC generally uses a single paygrade (the modal) for each personnel type/personnel designator combination. In order to reduce the planner's input requirements, pay and allowance factors for each paygrade have been stored as part of the model.

Civilian (Personnel Designator = 3 and 4)

Paygrade	Stored P&A Factor ($) for GS Civilians (3)	Stored P&A Factor ($) for WB Civilians (4)
18	39,060	
17	39,060	
16	39,060	
15	35,823	
14	30,377	15,157
13	28,053	14,773
12	22,285	13,845
11	18,935	13,373
10	17,041	12,758
9	15,717	12,127
8	14,254	11,471
7	13,828	11,077
6	11,782	10,527
5	10,483	9,587
4	9,266	9,214
3	7,953	8,896
2	6,447	8,491
1	5,651	7,912
Blank or 0 (Overall Average)	12,599	11,464

Additionally, a dummy pay and allowance schedule has been set up for non-DoD students with 20 possible paygrades. However, because of the wide range of possible pay rates, typical values could not be established; and consequently, the stored values were set equal to zero. If the planner feels that non-DoD student pay and allowances are relevant to a particular costing exercise, then the pay factor override option should be employed to introduce the appropriate pay rate.

Columns 9-11 (3 column numeric field): The score of this type of student on the ASVADM test (0-100).

Columns 12-14 (3 column numberic field): The score of this type of student on the ASVMEC test (0-100).

Columns 15-17 (3 column numeric field): The ratio of male students to the sum of male and female students (0-1.0).

Columns 18-37 (five 4-column fields): Number of student entrants of this type in years 1-5.

Format 4: Instructor Inputs Card Limit = 25 - This card contains inputs pertaining to the size, turnover, and student loading of the instructor force.

Breakdown of Instructor Force - The course planner must determine the breakdown of total instructor force by personnel type (Air Force, Other DoD), personnel designator (officer, airman, civilian) and paygrade, and student load. Typical paygrades for each instructor type are provided in Table 12.

TABLE 12
TYPICAL INSTRUCTOR PAYGRADES

Instructor Type	Officer	Airman	Civilian
Academic, remedial or special requirements instructor	0 - 3	3 - 5	GS - 9
Evaluators and Supervisors	0 - 4	E - 6, E - 7	GS - 11

Columns 3-4 (2 column numeric field): Personnel Type: Numeric personnel type code as follows:

8 = Air Force Instructor

9 = Other DoD (Army, Navy) Instructor

Use of a code other than 8 or 9 will result in the deletion of that card.

Columns 5-6 (2 column numeric field): Personnel Designator: Numeric personnel designator code as follows:

1 = Officer
2 = Airman
3 = Civilian - GS
4 = Civilian - WB

Use of a code outside the range 1 through 4 will result in the deletion of that card.

Columns 7-8 (2 column numeric field): Paygrade: Standard U.S. Government numeric paygrade codes. The codes and stored pay factors are the same as those described for input format 3. As before, the code entered in these columns must be within the range of permissible paygrades for the specific personnel designator or else the card will be deleted. A duplicate personnel type/personnel designator/paygrade combination will also cause a card to be deleted.

Columns 9-11 (3 column numeric field): Turnover rate (%): The percentage of instructors who will be replaced each year or the reciprocal of the average instructor's tour length in years times 100.

Columns 12-16 (5 column numeric field): Size of initial instructor cadre in year 0; the number of instructors (not manyears) brought onboard in year 0 for curriculum development and any required factory training.

Columns 17-19 (3 column numeric field): Students per Instructor: The number of students that can be instructed or counseled by an instructor of this type.

Format 5: Courseware Procurement Inputs Card Limit = 75 - The model recognizes four classes of courseware: (1) printed media such as textbooks and workbooks which are intended for both students and instructors; (2) printed media such as lesson and evaluation guides which are intended only for instructors; (3) display media such as films, slides, and charts; and (4) software such as teaching machine programs.

Four separate costs are estimated: (1) The initial cost of producing the master from which all subsequent copies will be made; (2) the cost of reproducing and packaging the required number of copies; (3) the annual cost of revision due to change in course content; and (4) the annual cost of replacement due to loss, damage, or normal aging The cost of courseware development, such as script writing and editing, is accounted for within curriculum manpower pay and allowances.

Columns 3-4 (2 column numeric field): Courseware ID Number: Unique number for each courseware type in range 1 through 99. A card will be deleted if its ID number duplicates that of another card or if its ID number falls outside the prescribed range.

Column 5 (1 column numeric field): Class: Numeric courseware class code as follows:

1 = Printed media for students and instructors (texts, workbook)
2 = Printed media for instructors only (lesson and evaluation guide)
3 = Display media (films, slides)
4 = Software (teaching machine programs)

Use of a code outside the range 1 through 4 will result in the deletion of that card.

Columns 6-27 (22 column alphanumeric field): Name of courseware: User-selected name for identifying each courseware type.

Columns 28-31 (4 column alphanumeric field): Name of courseware copies: User-selected name for identifying the unit denominator (book, reel, set) of each courseware type.

Columns 32-37 (6 column alphanumeric field): Name of courseware measure: User-selected name for identifying the unit of measure (pages, minutes, slides, etc.) for each courseware type.

Columns 38-41 (4 column numeric field): Total number of courseware measure per copy: The number of pages, slides, or minutes, etc., per unit of courseware.

Columns 42-46 (5 column numeric field): Initial preparation cost per courseware measure ($): The cost of producing a single measure of master courseware. Some typical values are provided in Table 13.

Columns 47-50 (4 column numeric field): Copy cost per courseware measure ($): The cost of copying a single measure of master courseware. Typical values are again provided in Table 13.

Columns 51-54 (4 column numeric field): Packaging cost per unit: The cost of cassettes, reels, trays, etc., per unit of courseware. Some typical values are as follows:

Sound on Slide Tray	$30.00
Slide Tray - 40 slides, straight	2.50
Audiotape Cassette	2.00
Video C[illegible] Tape ([illegible] minutes)	18.00
Video Cassette Tape (60 minutes)	25.00
Loose-leaf Binder (3-12", Telescoping Poles)	3.00

TABLE 13

TYPICAL COURSEWARE PROCUREMENT COSTS

	Courseware Measure	Initial Preparation Cost/ Courseware Measure Dollars	Copy Cost/ Courseware Measure Dollars
Printed Text	Pages	$1.50 - $4.50	.01
Sound Slide Set (Color)	Slides	50 - 1.00	.08
35mm Color Slide (Text)	Slides	4.50 - 9.00	.08
35mm Color Slide (Illustration)	Slides	7.50 - 25.00	.08
8mm Animated Sequence	Seconds	.40 - .85	-
Video Tape	Minutes	1.00 - 2.00	-

Columns 55-57 (3 column numeric field): Annual revision rate (%): The percentage of each courseware type's actual presentation minutes which can be expected to be revised annually due to changes in course content. These changes in course content could be caused by such things as modifications to mission equipment, a required upgrading of student capabilities, or an effort to improve the utilization of course resources. The model assumes that after the necessary revisions are made to the master, sufficient copies will be made of the revised portions (only) and integrated into the existing copies.

Columns 58-60 (3 column numeric field): Annual replacement rate (%): The percentage of each courseware type's units which will need to be replaced annually due to damage or normal aging.

Columns 61-64 (4 column numeric field): The number of lessons in the course utilizing this courseware. Courseware description need not limit it to only one lesson. For instance, several programmed text lessons could be grouped into one data entry. If blank, value is set equal to one.

Columns 65-67 (3 column numeric field): Number of simultaneous users per copy. This entry is used for courseware that is used simultaneously by more than one student, as in a four-man AV presentation. If blank, value is set equal to one.

Format 6: Curriculum Manpower Inputs Card Limit = 75 - Curriculum personnel determine training requirements and develop course written material. Normally, attached to the Curriculum Unit of a training department, these personnel share the task of courseware development with the course's instructors.

Columns 3-4 (2 column numeric field): Courseware ID number: The number used to identify the same courseware type in input format 5. A format 6 card will be deleted if its ID number does not have a match on a format 5 card, or if its ID number duplicates that of another format 6 card.

Columns 5-9 (5 column numeric field): Number of course hours: The number of course hours taken up by a given courseware type. This number should be coordinated with the number of lessons specified on card type 5 for this type of material.

Columns 10-14 (5 column numeric field): Number of curriculum manhours per course hour: The number of initial development curriculum manhours required for each course hour. Generally speaking, this number is a function of the teaching agent and the teaching format and is independent of the courseware type. Typical values are provided in Table 14.

Columns 15-47 (3 column numeric field): Percentage accomplished by instructors: The percentage of curriculum development done by the instructors rather than curriculum personnel.

Format 7: Hardware Procurement Inputs Card Limit = 75 - The model estimates four types of hardware costs: (1) the cost of purchasing the incremental number of units required each year, including initial replacement part stocks; (2) credits for any surplus items returned to the Stock Fund; (3) the annual cost of replacing those

TABLE 14

INITIAL COURSEWARE DEVELOPMENT
MANHOURS PER CONVENTIONAL COURSE HOUR

Presentation Media	Development* Manhours per Hour
Programmed Text	50 - 70
Audio Visual	80 - 100
Computer Assisted Instruction	100 - 300

*If new material is being written, without benefit of notes from the old course, these numbers should be increased by about 40%.

units worn out during the year; and (4) the annual cost of misecllaneous repair parts.

Columns 3-4 (2 column numeric field): Hardware ID number: Unique number for each hardware type in range 1 through 99. A card will be deleted if its ID number duplicates that of another card if its ID number falls outside the prescribed range.

Column 5 (1 column numeric field): Class: Numeric hardware class code as follows:

1 = media hardware (slide projectors, reel-to-reel projectors, tape recorders, teaching machines)

2 = special equipment (trainers, bailed aircraft)

3 = overhead hardware (chairs, desks)

Use of a code outside the range 1 through 3 will result in the deletion of that card.

Columns 6-35 (30 column alphanumeric field): Name of hardware type: User-selected name for identifying each hardware type.

Columns 36-39 (4 column numeric field): The number of units of a given hardware type which are available to a course at its inception, at zero cost.

Columns 40-47 (8 column numeric field): Procurement cost per unit ($). Normally, an AF planner will consult his own service's supply manual to determine hardware unit costs.

Column 48 (1 column numeric field): Credit Option: Option to obtain credit for surplus equipment returned to Stock Fund (yes = 1; no = 0 or blank). The planner may obtain credit for surplus equipment returned to the Stock Fund provided both the following conditions are met:

a. The unit cost does not exceed $1,000.

b. A demand exists elsewhere in the AF for the returned items.

The option should not be exercised if either the unit cost exceeds $1,000 or if other AF demand does not exist. In fact, if the planner enters a "1" for an item costing more than $1,000, then the model automatically resets the option designator value to "0." The planner should also enter a zero if any surpluses generated in a given year are to be retained for increased demands in subsequent years. The amount of the credit is 60% of the original purchase price, the other 40% assumed to go into rehabilitation action so that the equipment may again be sold at the full purchase price.

Columns 49-51 (3 column numeric field): Annual attrition rate (%): The percentage of hardware units which will need to be replaced each year. This value can be approximated by multiplying the reciprocal of the estimated average life (in years) by 100.

Columns 52-57 (6 column numeric field): Miscellaneous repair part cost per unit per year ($): The annual cost of purchasing repair parts for a single unit. In the absence of better data, a value in the range of 6 to 10% of the unit procurement cost should be used.

Columns 58-61 (4 column numeric field): Number of lessons using this type of hardware. More than one lesson may utilize the same type of hardware (such as an AV projector); this item allows the planner to specify this fact.

Columns 62-64 (3 column numeric field): The number of students who may simultaneously use hardware item. This is the number of students who are studying the same lesson that may simultaneously use this hardware device.

Format 8: Hardware Maintenance Manpower Inputs Card Limit = 75 - Hardware maintenance personnel are responsible for the preventive and corrective maintenance of course hardware. Media hardware maintenance is generally the responsibility of the Training Services Division (school-level), while all other types of hardware are usually serviced by the base Maintenance and Supply Group or a specialized maintenance squadron.

Columns 3-4 (2 column numeric field): Hardware ID number: The number used to identify the same hardware type in input format 7. A format 8 card will be deleted if its ID number does not have a match on a format 7 card or if its ID number duplicates that of another format 8 card.

Columns 5-10 (6 column numeric field): Number of failures per hour of use: The average number of times a particular type of equipment can be expected to fail for each hour of use.

Columns 11-15 (5 column numeric field): Average time to repair per failure (in hours). This value should include only that portion of downtime in which maintenance personnel are actively pursuing the repair activity.

Format 9: Facility Procurement Inputs Card Limit = 25 - This card contains inputs relating to the modification and construction of course facilities.

Columns 3-4 (2 column numeric field): Facility ID number: Unique number for each facility type in range 1 through 99. A card will be deleted if its ID number duplicates that of another card or falls outside the prescribed range.

Columns 5-34 (30 column alphanumeric field): Name of facility type: User-selected name for identifying each facility type.

Columns 35-38 (4 column numeric field): Units available "as is" at start of first year: The number of units of a given facility type which are available to a course at its inception at zero cost.

Columns 39-45 (7 column numeric field): Construction cost per unit ($): The cost of constructing or modifying a single facility unit.

NOTE: If unit requirements for a given facility type are assumed to be available at zero cost for all years under study, then the user should enter a unit construction cost of zero.

Columns 46-49 (4 column numeric field): The number of students who can simultaneously use the facility. An example is the number of students who can simultaneously use a laboratory.

Format 10: Facility Manpower Inputs Card Limit = 25 - Facility maintenance personnel are responsible for the maintenance and repair (including custodial service) of course facilities.

Columns 3-4 (2 column numeric field): Facility ID number: The number used to identify the same facility type in input format 9. A format 10 card will be deleted if its ID number does not have a match on a format 9 card or if its ID number duplicates that of another format 10 card.

Columns 5-10 (6 column numeric field): Square feet per facility unit.

Columns 11-16 (6 column numeric field): Maintenance manhours per square foot per month.

Format 11: Training Administrative, Base Operating Support, and Medical Manpower Inputs Card Limit = 3 - This card contains inputs required for the derivation of training administrative, base operating support, and medical manpower.

Training administrative personnel perform training-related overhead functions not otherwise accounted for. This includes functions at the school-level (Administrative Affairs Office), at the department level (Administrative Section, Requirements Unit, and Instruction and Measurement Unit), and at the branch level (branch administration). It does not include the functions provided by the Training Services Division or the Instructor Training Division (school level) or the Curriculum Unit (department level), however.

Base operating support personnel perform the following base housekeeping and service functions: supply, transportation, security police, material staff, comptroller, personnel staff, food, commissary, housing, laundry and dry cleaning, recreation, education, transient aircraft maintenance, and general (not course specific) facility maintenance. Medical personnel provide medical and dental care to military personnel.

Columns 3-4 (2 column numeric field): Personnel Type: Numeric personnel type code as follows:

13 = Training Administrative
14 = Base Operating Support
15 = Medical

Columns 5-6 (2 column numeric field): Set to 01.

Columns 7-11 (5 column numeric field): Number of fixed manyears per course for support services.

Columns 12-16 (5 column numeric field): Number of variable manyears per Type A manyear for support services..

Columns 17-21 (5 column numeric field): Number of variable manyears per Type B manyear for support services.

Typical values for these parameters are shown below. Type A manyears are the sum of student, instructor, and curriculum personnel manyears. Type B manyears are the military TDY student manyears.

	FIXED MANYEARS PER COURSE	VARIABLE MANYEARS PER TYPE A MANYEAR	VARIABLE MANYEARS PER TYPE B MANYEAR
Training Administrative	3	.05	--
Base Operating Support	0	.08	.035
Medical	0	.02	.005

Format 12: Computer Management System Inputs Card Limit = 3 - The three hardware items of the computer management system are:

CLASS	ITEM
01	Mainframe (CPU and Main Memory)
02	Management Terminals
03	Auxiliary Storage

For each of these, the following data are entered:

- o Hardware class: as designated above
- o Hardware name: user selected name
- o Capacity of unit: for mainframe and management terminals, this is the number of CMI transactions per hour; for the auxiliary storage it is the number of student data sets (complete records of one student) that can be stored.
- o Yearly cost of unit: Total yearly cost of the unit; if leased or purchased, maintenance costs should be included.

Columns 3-5 (one column field): Hardware class.

Columns 6-35 (30 column alphanumeric field): Name of hardware device.

Columns 36-40 (5 column numeric field): Capacity of unit.

Columns 41-46 (5 column numeric field): Yearly cost of unit.

Format 13: Optional Officer/Airman/Civilian Distribution Overrides - This card provides the planner the option of overriding stored officer/airman/civilian distribution percentages. It is one of two input formats on which blanks and zeroes are differentiated. Thus, the planner needs to make entries only in the fields of those personnel types whose distribution he wishes to override; the other fields should be left blank. If the override values for a given personnel type do not total 100, then the model reinstates the stored values. The stored values are as follows:

	Officer %	Airman %	Civilian %
Curriculum	0	63	37
Hardware Maintenance	2	72	26
Facility Maintenance	0	100	0
Training Administrative	6	39	55
Base Operating Support	2	64	34
Medical	20	80	0

Columns 3-11 (three 3 column numeric fields): Curriculum manpower officer/airman/civilian distribution.

Columns 12-20 (three 3-column numeric fields): Hardware maintenance manpower officer/airman/civilian distribution.

Columns 21-29 (three 3-column numeric fields): Facility maintenance manpower officer/airman/civilian distribution.

Columns 30-38 (three 3-column numeric fields): Training administrative manpower officer/airman/civilian distribution.

Columns 39-47 (three 3-column numeric fields): Base operating support manpower officer/airman/civilian distribution.

Columns 48-56 (three 3-column numeric fields): Medical manpower officer/airman/civilian distribution.

Format 14: Optional Miscellaneous Overrides - This card allows the planner to override miscellaneous time and cost factors which have been stored as part of the program. It is the second of two input formats on which blanks and zeroes are differentiated. Thus, as before, the planner needs to make entries only in the fields of those factors which he wishes to override; the other fields should be left blank. The stored values are as follows:

Available Productive Manhours/Month	
Hardware Maintenance Personnel	121
All other Personnel Types	142
Average Number of Training Days per Month	21.7
Classroom Training Hours per Student per Day	7
Miscellaneous Supply Cost per Manyear ($)	112
PCS Cost per Move ($)	
Officer	879
Airman	224
Civilian	879
TDY Expense ($)	
One-Way Transportation	85
Destination per Diem	
Officer	11
Airman	4
Civilian	21

Columns 3-10 (two 3-column numeric fields): Available productive manhours per month. Most AF training personnel have 142 hours per month available to perform productive work (174 assigned hours less 32 hours for leave, medical, training, and organizational duties). Hardware maintenance personnel, however, must spend part of that 142 hours waiting for parts and tools. This waiting time is estimated at 15% of available hours, thus reducing hardware maintenance available productive manhours per month to 121.

Columns 11-14 (4 column numeric field): Average number of training days per month.

Columns 15-18 (4 column numeric field): Classroom training hours per student per day. This value should coincide with the value listed on Worksheet 1.

Columns 19-23 (5 column numeric field): Miscellaneous supply cost per student per manyear: The cost of personnel supplies (food, clothing, etc.) and general office supplies (paper, pencils, forms, etc.) per manyear (students and permanent party).

Columns 24-35 (three 4-column numeric fields): PCS (.rmanent Change of Station) cost per move ($): Includes transportation of personnel and dependents; shipment and/or storage of household goods; and mileage per diem and subsistence allowance while in travel status.

Columns 36-39 (4 column numeric field): Average TDY one-way transportation cost ($): Average cost of transportation and travel per diem to or from technical training center.

Columns 40-48 (three 3-column numeric fields): TDY destination per diem ($): Average student cash entitlement while at technical training centers, after deductions for quarters and messing (when available).

Format 15: Optional Pay and Allowance Overrides - This card permits the planner to override the stored pay and allowance factors. The stored values are listed in Figure 10.

Columns 3-4 (2 column numeric fields): Personnel designator: Numeric personnel designator code as follows:

1 = Officer
2 = Airman
3 = Civilian - GS
4 = Civilian - WB
5 = Non-DoD

Use of a code outside the range 1 through 5 will result in the deletion of that card.

Columns 5-6 (2 column numeric field): Paygrade: Standard U.S. Government numeric paygrade codes. Card deletion will occur if the paygrade entered is not within the range of permissible paygrades for that personnel designator or if the personnel designator/paygrade combination duplicates that of another card.

Personnel Designator	Permissible Paygrade Range
Officer	0 or blank, 1-10
Airman	0 or blank, 1-9
Civilian - GS	0 or blank, 1-18
Civilian - WB	0 or blank, 1-14
Non-DoD	0 or blank, 1-20

Columns 7-11 (5 column numeric field): Annual pay and allowance factor ($): Annual pay and allowances per manyear.

Format 16: Lesson Descriptor Cards Card Limit = 75 - This card is used to describe each lesson in the new self-paced course. Thirteen descriptors are needed for each lesson. These variables are described in paragraph 4.2.2 of the report.

Columns 3-5 (3 column numeric field): Lesson ID number; a sequencing number assigned by the planner. This is used only for convenience in arranging the lessons. It is not used in the computations.

Columns 6-25 (20 column alphanumeric field): Lesson name; user selected name for lesson.

Columns 26-30 (5 column numeric field): The number of lecture/discussion minutes in the conventional course (CLDM). Taken directly from the POI.

Columns 31-35 (5 column numeric field): The number of demonstration/performance-cognitive minutes in the conventional course lesson (CDPMC). Taken directly from the POI.

Columns 36-40 (5 column numeric field): The number of minutes of memory content in the lesson (MEM). Provided by the course developer.

Columns 41-45 (5 column numeric field): The numerical rating from 0 to 5 of the simplicity or complexity of the memory content in the lesson (MSC). Provided by the course developer.

Columns 46-50 (5 column numeric field): The number of self-check items in the self-paced course lesson (SCKC). A design variable.

Columns 51-55 (5 column numeric field): The number of minutes of psychomotor task content in the lesson (PM). Provided by the course developer.

Columns 56-60 (5 column numeric field): The number of programmed instruction/ audiovisual minutes in the conventional course lesson (CPIAVM). Taken directly from the POI.

Columns 61-65 (5 column numeric field): The number of demonstration/performance-psychomotor minutes in the conventional course lesson (CDPMP). Taken directly from the POI.

Columns 66-70 (5 column numeric field): The numerical rating from 0 to 5 of the simplicity or complexity of the psychomotor content in the lesson (PMSC). Provided by the course developer.

Columns 71-75 (5 column numeric field): The number of minutes of cognitive content in the lesson (COG). Provided by the course developer.

Columns 76-80 (5 column numeric field): The number of outside assignment minutes in the conventional course (COUTM). Taken directly from the POI.

Format 99: Termination Card - No entries other than the "99" in columns 1 and 2 need be made.

Computer Program Output Description

The output from the computer program is illustrated in this section through the use of an example run from the program. Since much of the output format remains as it was designed by Rand for the MODCOM Program, we have summarized their descriptions as in MODIA: The Cost Model (Hess & Kantar, 1976). The user of the model will note that some small rounding errors occur in the totals.

Output 1 (Figure A-1) - This is an exact echo of the input data. Card columns are shown on the top of the page so any misalignment of data or input is apparent.

Output 1a (no figure) - This section contains error messages relating to data that were found to be outside the specified range, or from duplicate cards. Fatal errors, such as no lesson descriptors or the omission of the end of data card (Format 99) will also appear here.

Output 2 (Figure A-2 - This output lists the values assigned to each variable in the lesson descriptor set. Only those lessons which have passed the tests for acceptable range appear here.

Output 3 (Figure A-3) - This table lists the computed time to complete each lesson for students with various student variable values. Times are shown in hours. Total course time for each time student is shown, as well as the weighted average time to compelte the course, and the percentage timesaving (if TPOI is given).

Output 4 (Figure A-4) - This output lists the personnel distributions and cost factors stored as part of the model. These may be overridden by inputting data (Formats 14-16).

Output 5, Graduat Summary (Figure A-5) - Output 5 is a time-phased summary of Active Duty Force, Guard and Reserve, other DoD and Non-Dod graduates. The numbers reflect only those students who actually graduate in that year. For example, if the course duration were greater than one year, then no graduates would appear in year 1. The "in progress" column indicates the number of students who entered in years 4 and 5 but who will not graduate until years 6 or 7. All Air Force students except those assigned to the Air National Guard and the Air Force Reserve are termed Active Duty Force. Guard and Reserve refers only to Air Force Guard and Reserve students. Students assigned to DoD agencies other than the AF, such as the Army and Navy (including their Guard and Reserve components) are classified as other DoD. Finally, students from non-DoD agencies, including foreign governments (e.g., Military Assistance Program), are termed Non-DoD.

Output 6, Manpower Summary (Figure A-6) - Output 6 is a two part, time-phased summary of student and base permanent party manyears. Part 1 is a functional breakdown covering all course personnel while Part 2 is a PCS/TDY breakdown limited to AF personnel.

Part 1

Total Student Load: Total student manyears.

Instructors include all academic, remedial and special requirements instructors as well as course monitors and supervisors.

Curriculum Personnel determine training requirements and develop course written materials. Normally attached to the Curricula of a training department, these personnel share the task of courseware development with the course's instructors.

Hardware Maintenance Personnel are responsible for the preventive and corrective maintenance of course hardware. Media hardware maintenance is generally the responsibility of the Training Services Division (school level), while all other types of hardware are usually serviced by the base Maintenance and Supply Group or a specialized maintenance squadron.

Facilities Maintenance Personnel are responsible for the maintenance and repair (including custodial service) of course-related facilities.

Training Administrative Personnel perform training-related overhead functions not otherwise accounted for. This includes functions at the school level (Administrative Division, Training Evaluation Division, Operations Division, and Foreign Military Affairs Office), at the department level (Administrative Section, Requirements Unit, and Instruction and Measurement Unit), and at the branch level (branch administration). It does not include the functions provided by the Training Service Division or the Instructor Training Division (school level) or the Curricula Unit (department level), however.

Base Operating Support (BOS) personnel perform the following base housekeeping and service functions: supply, transportation, security police, material staff, comptroller, personnel staff, food, commissary, housing, laundry and dry cleaning, recreation, education, transient aircraft maintenance, and general (not course specific) facility maintenance.

Medical Personnel provide medical and dental care to military personnel.

Total Base Permanent Party represents those personnel assigned to a base for the purpose of performing duty in the furtherance of the mission of that base. Thus, students are excluded from this total.

Total Course Manyears represents total student load plus total base permanent party.

Part 2

Active Duty Force PCS Student Load: The number of PCS* manyears accrued by Active Duty Force students. Pipeline students are always assumed to be PCS while lateral and upgrade students are PCS only if the course duration is 20 weeks or more.

Base Permanent Party - AF Only: Total base permanent party less non-AF instructors. Specific program elements charged are:

Specialized Training

- Air Force Instructors
- Curriculum Personnel
- Hardware Maintenance Personnel
- Training Administrative Personnel

*Permanent Change of Station means the reassignment of a military person from one permanent duty station to another.

Hospitals

Medical Personnel assigned to hospitals

Real Property Maintenance Activities

Facilities Maintenance Personnel (course-related)

Facility-related portion of BOS Personnel (general base housekeeping)

Base Operations

BOS Personnel (except facility-related portion)

Medical Personnel assigned to dispensaries

Active Duty Force TDY Student Load: Number of TDY* manyears accrued by Active Duty Force students including Program 8 TDY students. Pipeline students are never TDY while lateral and upgrade students are TDY only if the course duration is less than 20 weeks. They may be assigned to any program element in Air Force Programs 1-4 and 6-10.

Guard and Reserve Student Load: Number of manyears (PCS and TDY) accrued by Air Force Guard and Reserve students. All Guard and Reserve manyears are charged to Program 5.

Total Air Force Manyears: The sum of total Program 8 manyears, Active Duty Force TDY student manyears, and Guard/Reserve student manyears.

Output 7, Courseware, Hardware, and Facility Requirements (Figure A-7) - Output 7 is a summary of key courseware, hardware, and facility inputs and computer requirements.

Output 8, Functional Cost Summary (Figure A-8) - Output 8 is a breakdown of total course costs by function.

Investment Costs

Courseware Procurement includes four separate costs: (1) the initial cost of producing the master from which all subsequent copies will be made; (2) the cost of reproducing and packaging the required number of copies; (3) the annual cost of revision due to change in course content; and (4) the annual cost of replacement due to loss, damage, and normal wearout. It does not include the cost of courseware

**Temporary Duty means duty at a location other than the permanent duty station at which a member performs temporarily under orders which provide either reassignment to the old permanent station or assignment to a new permanent station.

development such as script writing and editing, which is accounted for within curriculum manpower pay and allowances.

Hardware Procurement embraces the following cost elements: (1) the cost of purchasing the incremental number of units required each year, including initial replacement part stocks; (2) credits for any surplus items returned to the Stock Fund; and (3) the annual cost of replacing those units worn out during the year. The annual cost of replenishment repair parts is accounted for elsewhere. Negative numbers indicate a dominance of Stock Fund credits.

Facility Construction represents the total cost of constructing and/or modifying facilities required for course use.

Operating Costs

Pay and Allowances provides for all officer, airman, and civilian pay and allowances. The elements accounted for are as follows:

Officers	Airmen	Civilian
Basic Pay	Basic Pay	Basic Pay
Special Pay	Special Pay	Life Insurance
Basic Allowance for Quarters	Proficiency Pay	Health Benefits
Basic Allowance for Subsistence	Reenlistment Bonus	Terminal Leave
Uniform Allowance	Basic Allowance for Quarters	Workman's Compensation
Family Separation Allowance	Clothing Allowance	Civilian Retirement
Separation Payments	Separation Payments	Overtime
Social Security Tax - Employer's Contribution	Social Security Tax - Employer's Contribution	

PCS Costs include the expenses incident to the permanent change of station of students and instructors: transportation of personnel and dependents; shipment and/or storage of household goods; and mileage per diem and subsistence allowances while in travel status.

TDY Costs include commercial transportation, car rental, mileage allowances and tools, per diem, and incidental expenses incurred by students in authorized travel status.

Instructor Training is composed of instructor education training costs (the cost of the six-week instructor prerequisite course on education principles) and initial factory training costs (the cost of providing the initial instructor cadre with necessary specialized equipment or system training).

Miscellaneous Operating Costs consists of three distinct elements:

1. Computer Service Charges: Any computer expenses incurred as a result of using computer based instruction.
2. Hardware Replenishment Repair Parts: The cost of purchasing miscellaneous hardware repair parts.
3. Miscellaneous Supplies: The cost of personnel supplies (food, clothing, etc.) and general office supplies (paper, pencils, forms, etc.).

The planner should carefully inspect each type of output to assure himself that the answers are reasonable. Areas where large costs appear may focus further planning effort to reducing these costs.